A GENERAL ROUTE TO [m] [n] CYCLOPHANES

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C. U. H. K.
June, 1983

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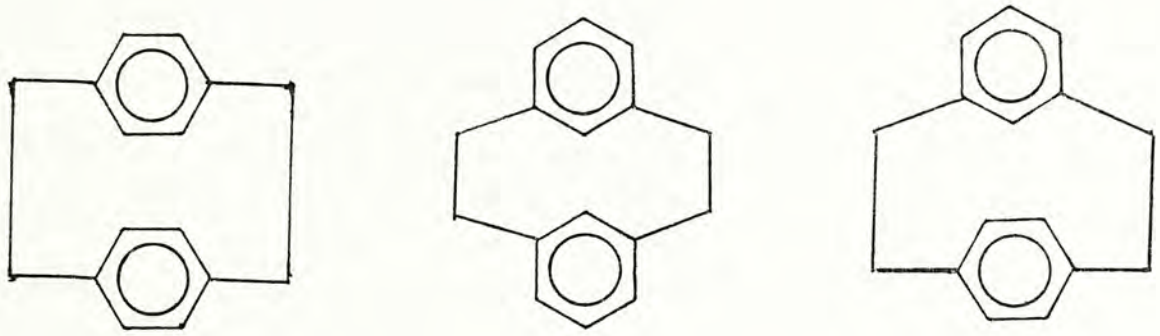
ABSTRACT

A new synthetic route to [m][n]cyclophanes is described. This method evokes the use of sulfur-mediated cyclocoupling reaction in conjunction with ring-contraction by the Meyers' modification of the Ramberg-Bäcklund rearrangement. The key steps in the nine-reactions scheme involve the bischloromethylation of [n]cyclophanes, the cyclocoupling of the bis(chloromethyl)[n]cyclophanes with α,ω-alkanedithiols, and the extrusion of sulfur dioxide of [m+2][n]dithiacyclophane bissulfones. Its broad synthetic utility has been demonstrated by the successful preparation of four hitherto unknown [m][n]cyclophanes, namely, [8][12]metacyclophane, [12][12]metacyclophane, [12][12]-paracyclophane, and [12][14]paracyclophane, in which the benzene ring is chained in different manners by two methylene bridges of various lengths.

CONTENTS

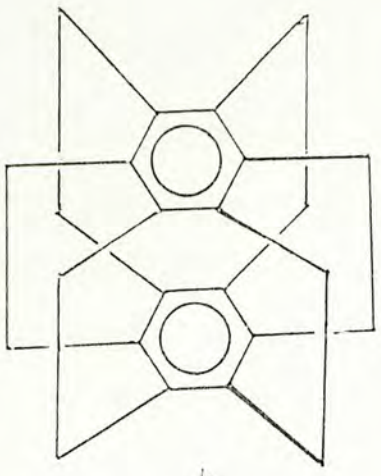
I. INTRODUCTION

The term "phane" refers to any organic molecule containing at least one aromatic nucleus and at least one aliphatic bridge[1]. Cyclophanes, which feature one or more benzene rings as the aromatic moieties, belong to a subgroup of this class of compounds. [2.2]Paracyclophane (1), [2.2]metacyclophane (2), and [2.2]metaparacyclophane (3) are the most well known examples in which two benzene rings are held in juxtaposition by two ethano bridges.



1 2 3

The conformational rigidity of the σ-framework in these systems renders them unique vehicles for testing all aspects of questions of strain, bonding, and transannular π-π electronic interaction. Thus, the synthesis of cyclophanes has been an active area of study with phenomenal growth[2] in the past three decades, culminating in the recent report by Boekelheide on the synthesis of superphane (4)[2g,3], a molecule which withstands structural torture



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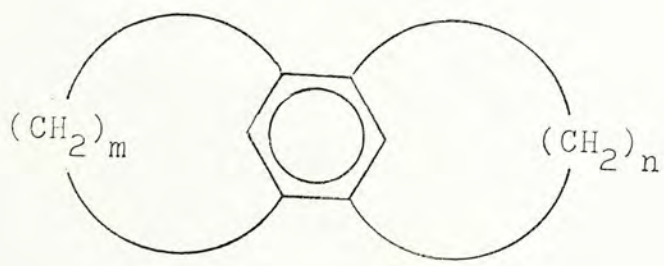
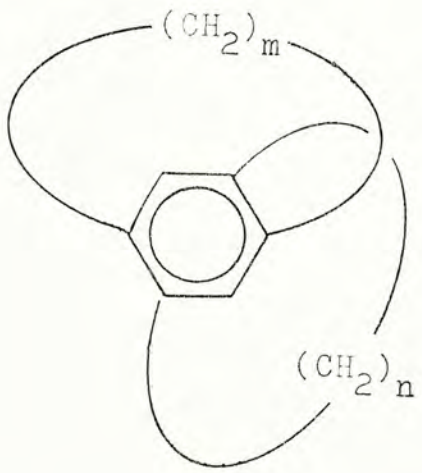
to an extreme matched by only a few other systems. In the course of this development, a large number of novel cyclophanes has been successfully synthesized. The long list includes the highly strained [6]- and [7]paracyclophanes[4], multilayered and multistepped cyclophanes[2e], and multibridged double-layered [2$_n$]cyclophanes[2g,h]. However, very little attention has been given to the synthesis of double-bridged monolayered [m][n]cyclophanes (5). In fact, at the outset of the present investigation,



5a

[m][n]Metacyclophane



5b

[m][n]Paracyclophane

the only known [m][n]cyclophanes were [8][8]- and [8][10]para-cyclophanes reported by Nakazaki and coworkers[5], and, more surprisingly, none of the [m][n]metacyclophanes were known.

[m][n]Cyclophanes are structurally remarkable since they possess "hollow" interior sites into which in principle smaller chemical species may be entrapped. In addition, [m][n]para-cyclophanes are topologically interesting in that they can be resolved into enantiomeric antipodes by virtue of molecular dissymmetry. It was therefore the objective of the present study to explore general synthetic routes to [m][n]cyclophanes amenable to structural variations in respect of both the length of the bridges and the anchoring points on the benzene ring.

II. LITERATURE SURVEY

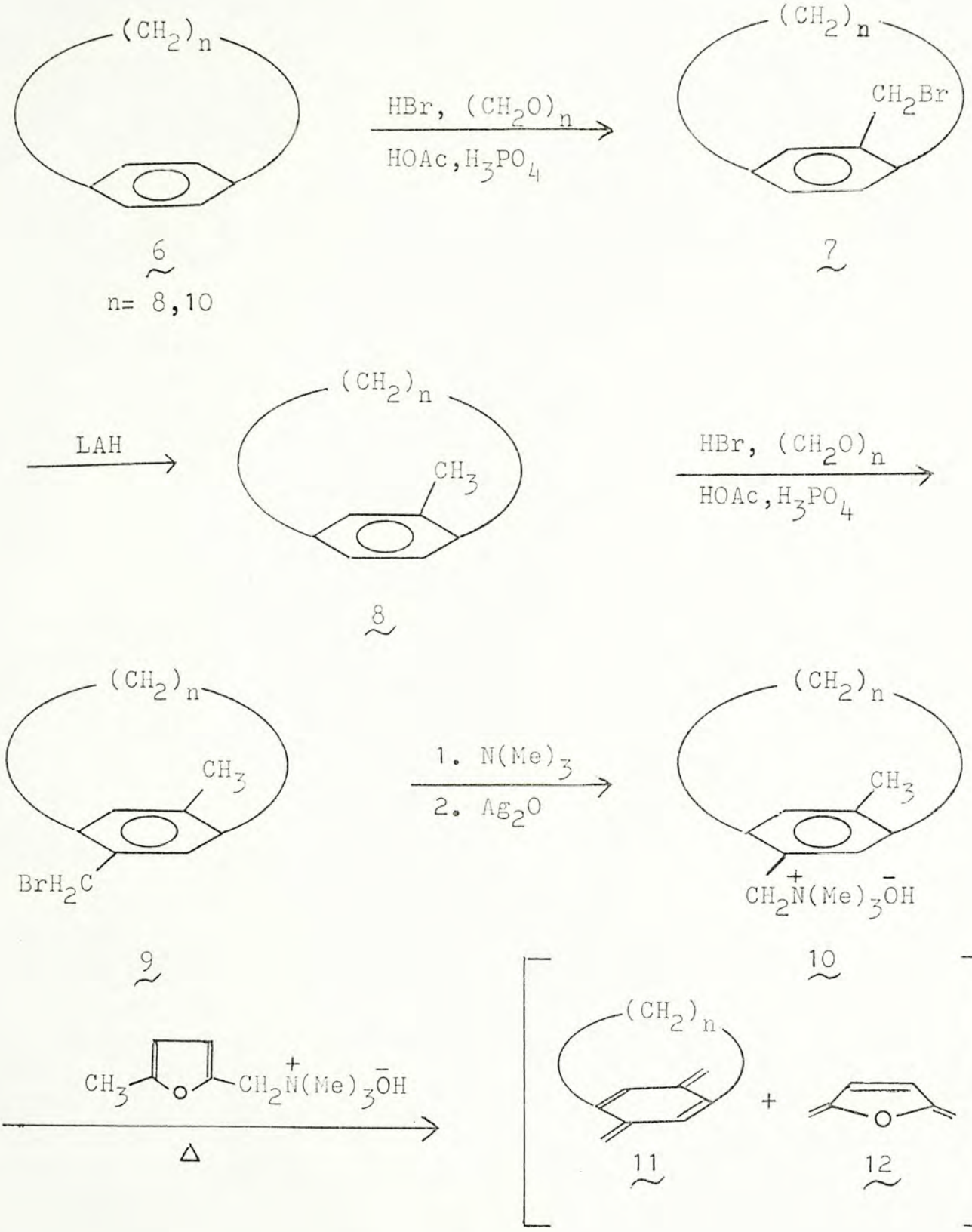
As mentioned above, the only known [m][n]cyclophanes were [8][8]- and [8][10]paracyclophanes reported by Nakazaki[5]. Our interest in these systems stemmed from Li's previous synthetic approach to [n]cyclophanes[6] in this laboratory. It was envisaged that if a handle of cyclization could be constructed on the benzene moiety of [n]cyclophanes, a second bridge could be assembled to provide various [m][n]cyclophanes. In order to supply a framework of reference for the discussions to be presented in the latter sections of this Thesis, a brief review of the previous works of these authors is given below.

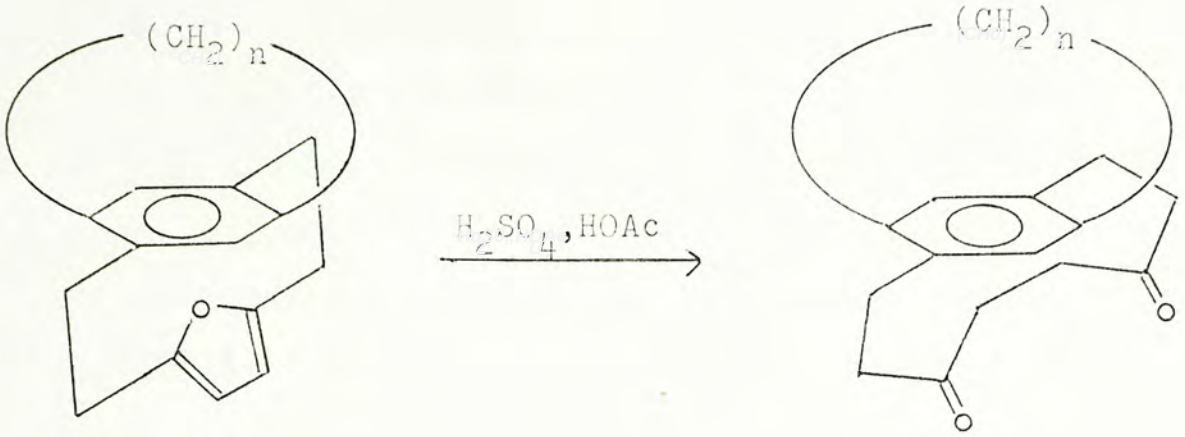
II.1. Nakazaki's Approach to [8][8]- and [8][10]Paracyclophanes

The elegant synthetic route developed by Nakazaki[5] to [8][8]- and [8][10]paracyclophanes (16) pivoted on a coupling reaction of the para-bridged p-xylylene derivatives 11 with 2,5-dimethylene-2,5-dihydrofuran (12) to furnish the benzene-furan "hybrid" [2.2]paracyclophanes 13 whose furan moieties were subsequently transformed to give the second octamethylene bridges. The overall synthetic route is shown in Scheme I.

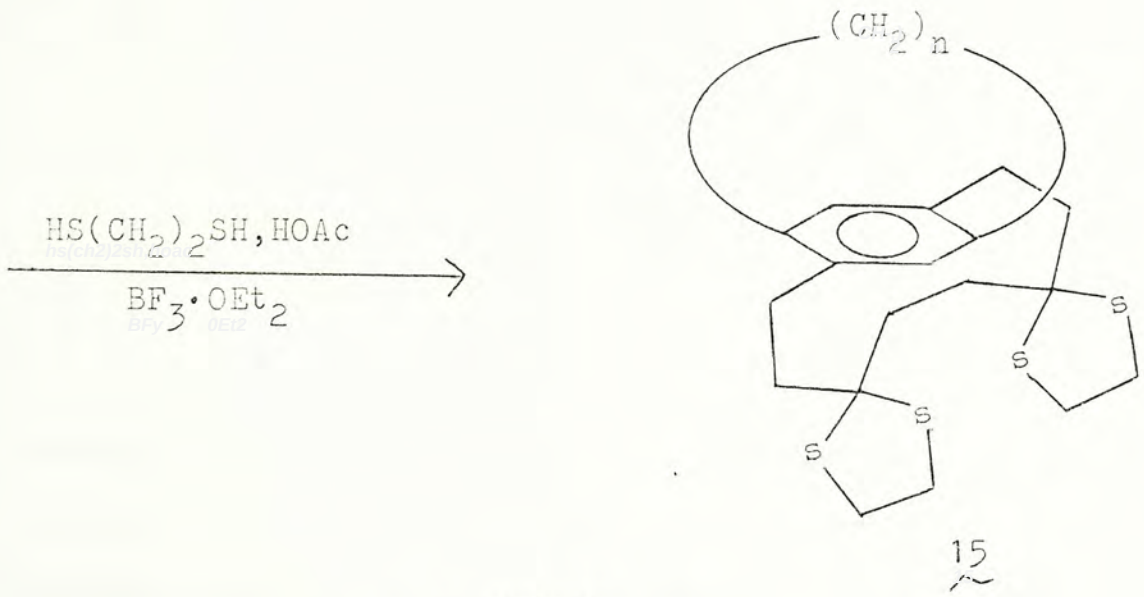
Bromomethylation of paracyclophanes 6 gave the corresponding bromomethyl derivatives 7 which were reduced by lithium aluminum hydride to the methylparacyclophanes 8. Further bromomethylation of 8 furnished bromides 9 which were converted into the Hofmann bases 10. Pyrolysis of 10 with 5-methylfur-

Scheme I. Synthesis of [8][8]- and [8][10]Paracyclophanes (16) by Nakazaki





13 14



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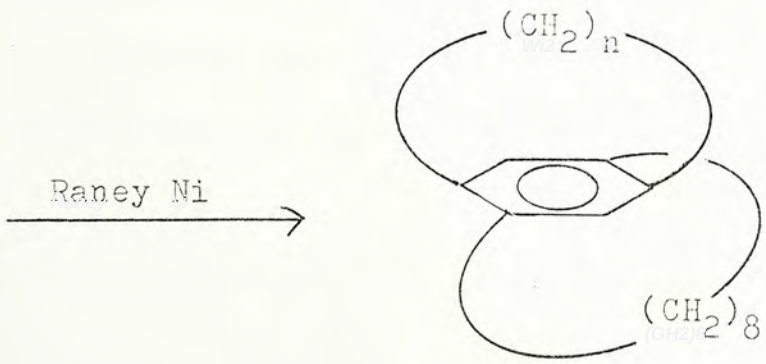
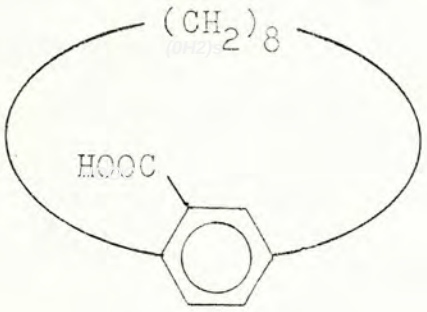


16

n= 8, 10

furyltrimethylammonium hydroxide provided the benzene-furan "hybrid" [2.2]paracyclophanes 13 among other products. Hydrolysis of 13 gave diketones 14 which were reduced to [m][n]paracyclophanes 16 via the thioketals 15.

By a slightly modified procedure[5c], using optically active (+)-[8]paracyclophane-10-carboxylic acid (17), (+)-[8][8]paracyclophane was obtained. Similarly, (-)-15-methyl[10]paracyclophane-12-carboxylic acid (18) led to (-)-[8][10]paracyclophane[5c]. The



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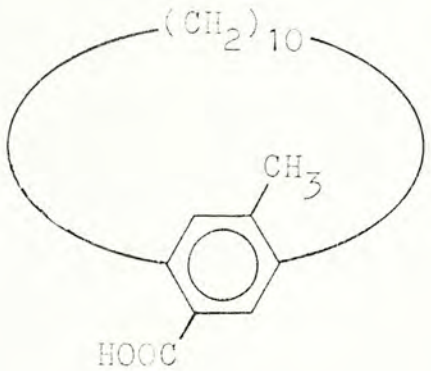

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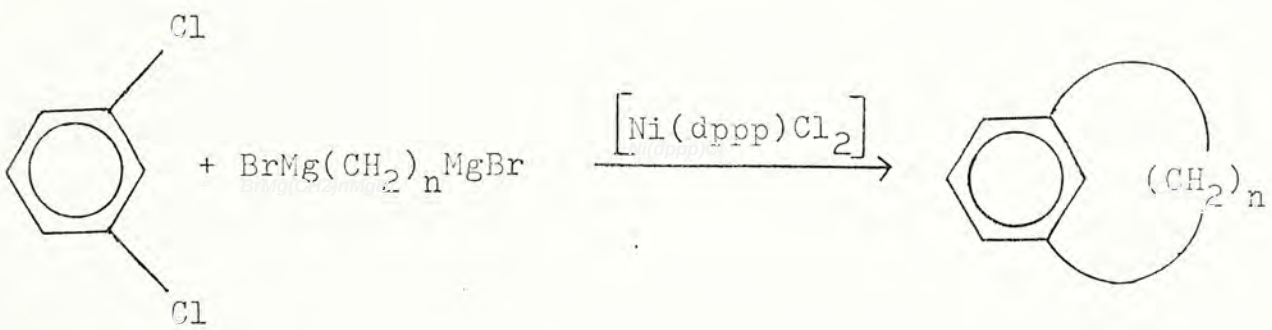
remarkable feature in Nakazaki's methodology is its capability of providing optically active [m][n]paracyclophanes. Nevertheless, its synthetic applicability is limited in a sense that one of the bridges in the final product must carry eight methylene units.

II.2. Synthesis of [n]Cyclophanes by the Modified Ramberg-Bäcklund Rearrangement

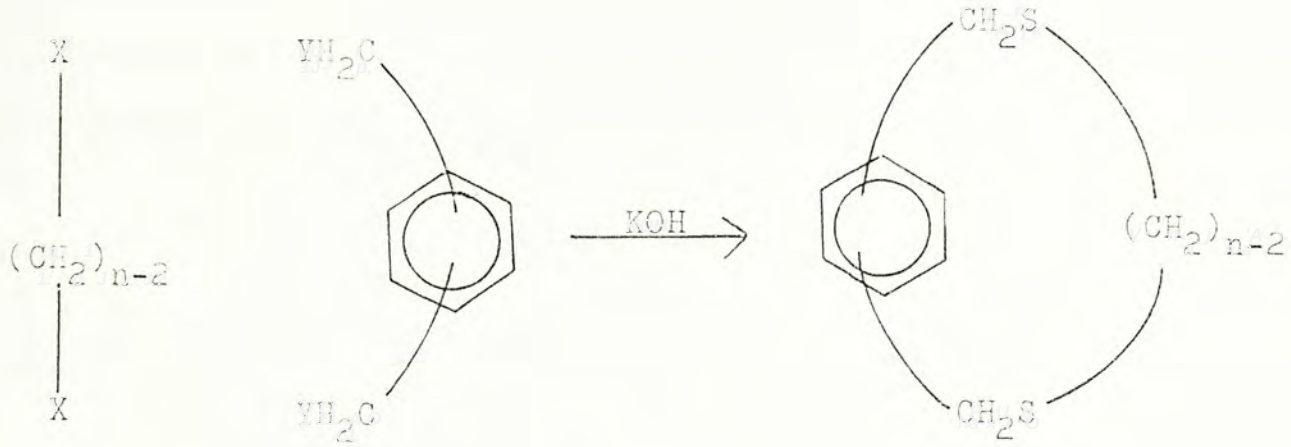
It is obvious that the most straightforward approach to [m][n]cyclophanes is to construct a second bridge on any given [n]cyclophane. Therefore the availability of these precursors in sizable quantities is of primary concern.

In the early days of the era of cyclophane chemistry, [n]cyclophanes were prepared by Cram[7] using the acyloin condensation of appropriately constructed diesters of benzenedialkanoic acids. Kumada and coworkers[8] later developed a one-step procedure involving the cyclocoupling reactions of the di-Grignard reagents of α,ω-dibromoalkanes with aromatic dihalides in the presence of a catalytic amount of dichloro-[1,3-bis(di-phenylphosphino)propane]nickel(II). However, this

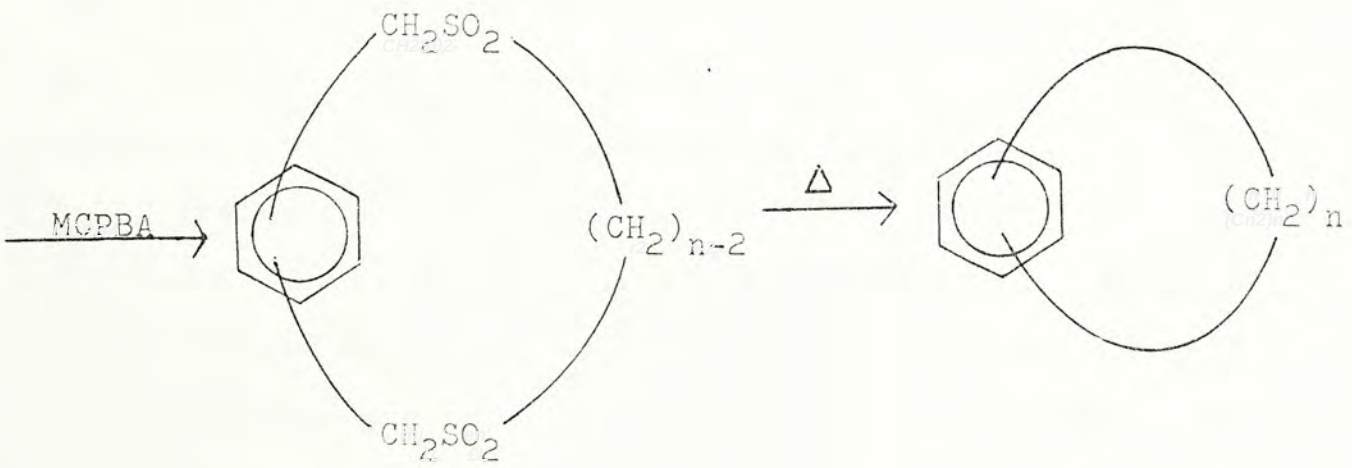


reaction was applicable only for the preparation of [n]metacyclophanes and the yields were at best marginal. More recently, Misumi and coworkers[9] reported a versatile route to [n]cyclophanes. The key step involved the pyrolytic extrusion

of sulfur dioxide from the [n+2]dithiacyclophane bissulfones (19) which were prepared by the cyclocoupling of suitable dithiols and dihalides followed by oxidation of the resulting [n+2]dithiacyclophanes. A series of [n]paracyclophanes (n= 8 - 12 , and 14) and [n]metacyclophanes (n = 7 and 10) were obtained



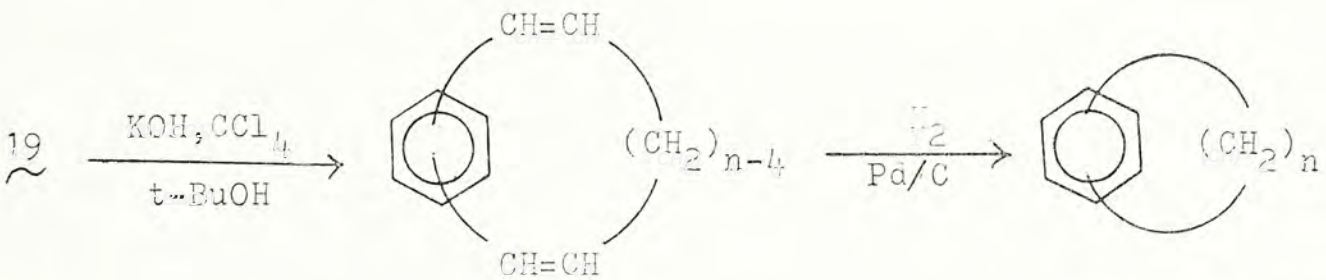
X= SH or Br Y= SH, Cl, or Br



19

in this manner in 48-67% yields. Notwithstanding the general utility of Misumi's method, it is inconvenient to carry out the pyrolytic reaction in large preparative scale.

As part of a continuing interest in designing effective methodology for cyclophane synthesis in our laboratory, Li[6] has previously devised a particularly useful procedure for preparing sizable quantities of [n]cyclophanes. The key step in the reaction sequence involved a modified Ramberg-Bäcklund rearrangement on the [n+2]dithiacyclophane bissulfones 19



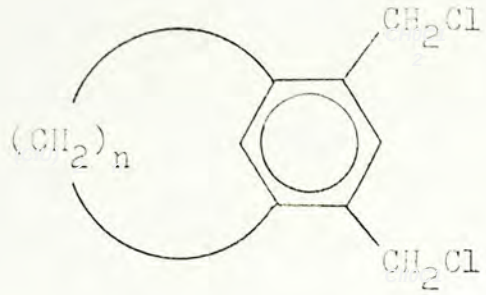
which were prepared in the usual manner. In the presence of pulverized potassium hydroxide in carbon tetrachloride – t-butanol, bissulfones 19 underwent sulfur dioxide extrusion to give the corresponding [n]cyclophanedienes 20 which on hydrogenation led smoothly to a variety of [n]cyclophanes.

The synthetic route developed by Li offers an attractive alternative for the preparaton of [n]cyclophanes. Its advantages include mild reaction conditions, simple experimental manipulations, and adaptability to large scale preparations.

III. SYNTHETIC PLANS

In the previous section, the only existing synthetic method for [m][n]cyclophanes together with a general procedure for the preparation of the required precursors—the [n]cyclophanes were reviewed. As our goal was aimed to devise a general route to [m][n]cyclophanes amenable to variation in the length of both bridges as well as in the manner in which the benzene ring is anchored, the previous methodology developed by Nakazaki, with its inherent limitation (*vide supra*), did not appear to suit our purpose.

With at our disposal a reliable access to the [n]cyclophanes, we were left with the relatively simple task to introduce onto the benzene nucleus appropriate functionalities upon which the second bridge could be built. Of various possibilities contemplated, the bischloromethylation procedure appeared to be most straightforward. No serious difficulties were anticipated for preparing the bis(chloromethyl)[n]cyclophanes, since the benzene ring would be sufficiently activated for this type of reaction. Furthermore, as the directive effect of the methylene bridges would not greatly differ from that of the two methyl groups, the points of entry of the two chloromethyl groups would be easily predicted. Thus, [n]metacyclophanes and [n]paracyclophanes were expected to give dichlorides



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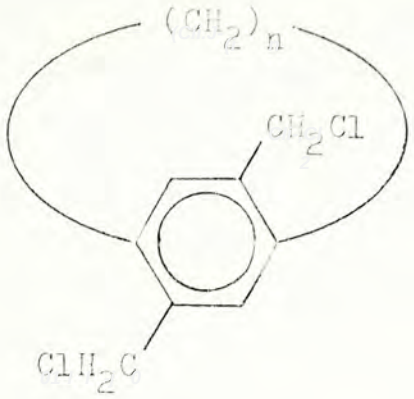
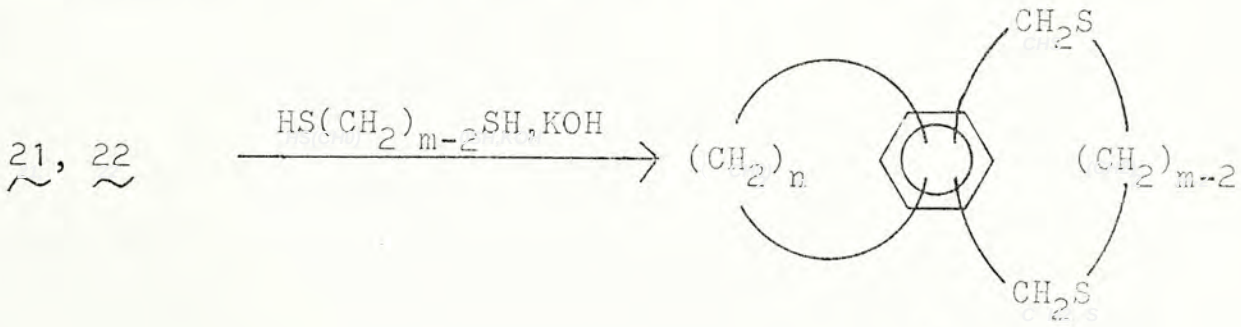


22

21 and 22, respectively, in a manner analogous to the behaviour of m- and p-xylenes[10].

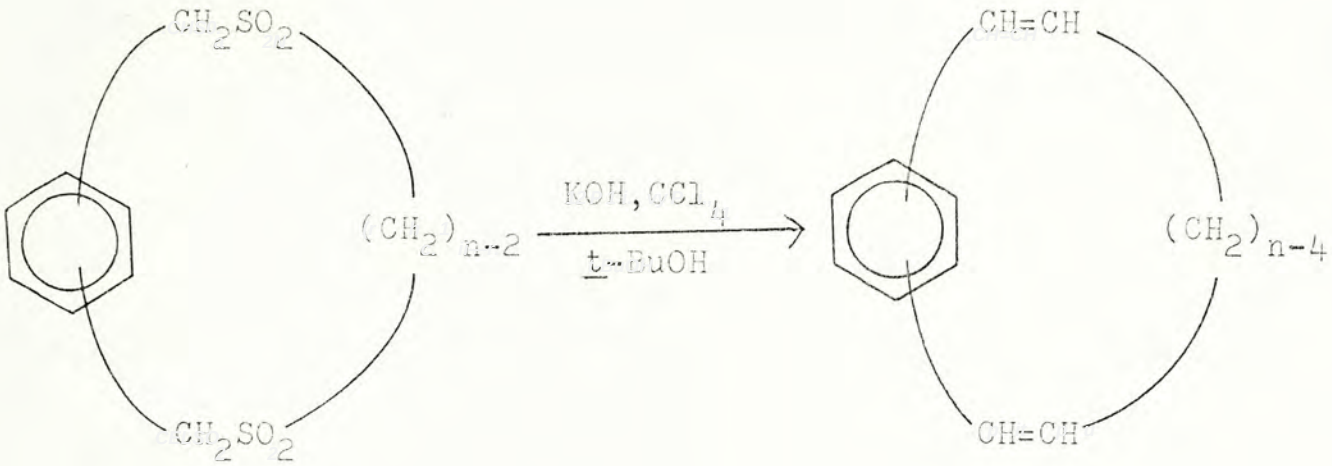
The two chloromethyl substituents in 21 and 22 would be excellent handles of cyclization for the construction of the second bridge. The remarkable high yields encountered in the synthesis of cyclophanes by the dithiacyclophane-sulfur extrusion procedure[2g-i,11-18] rendered this approach an attractive method to meet our synthetic objectives. Therefore, should dichlorides 21 and 22 be secured in sizable quantities, it would best be to convert them into [m+2][n]-dithiacyclophanes of the type depicted as 23. What



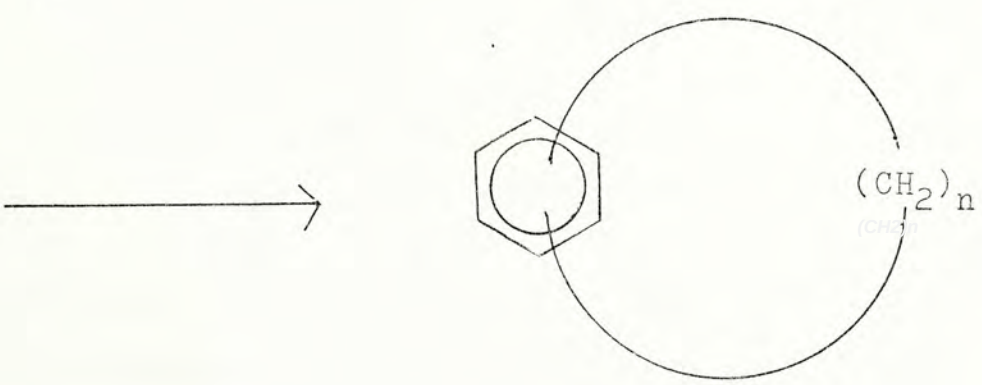
23

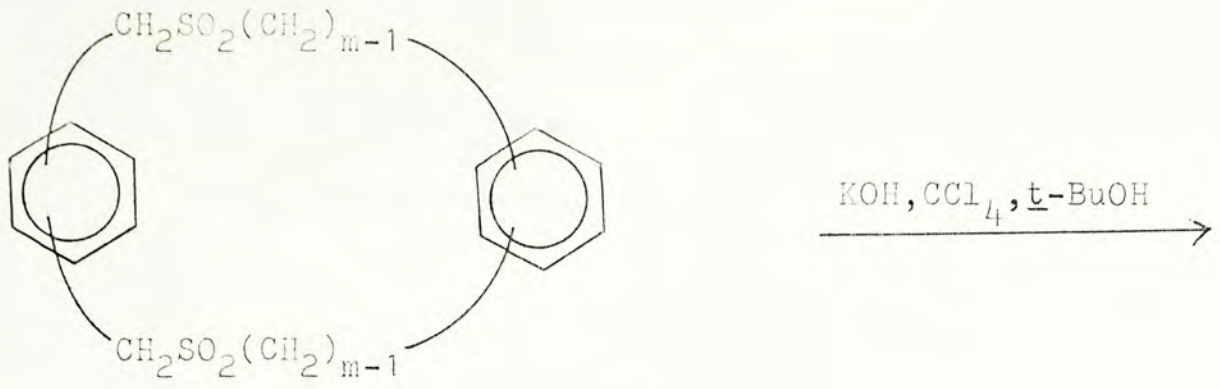
remained to be decided , however, was the methods for sulfur removal in 23.

The utilization of the Meyers' modification of the Ramberg-Bäcklund rearrangement[19,20] in cyclophane synthesis has been well scrutinized in our laboratory[6]. It was found that strain-free unilateral benzyl sulfones of the types 19 and 24, in most instance, could be transformed by this



19 20





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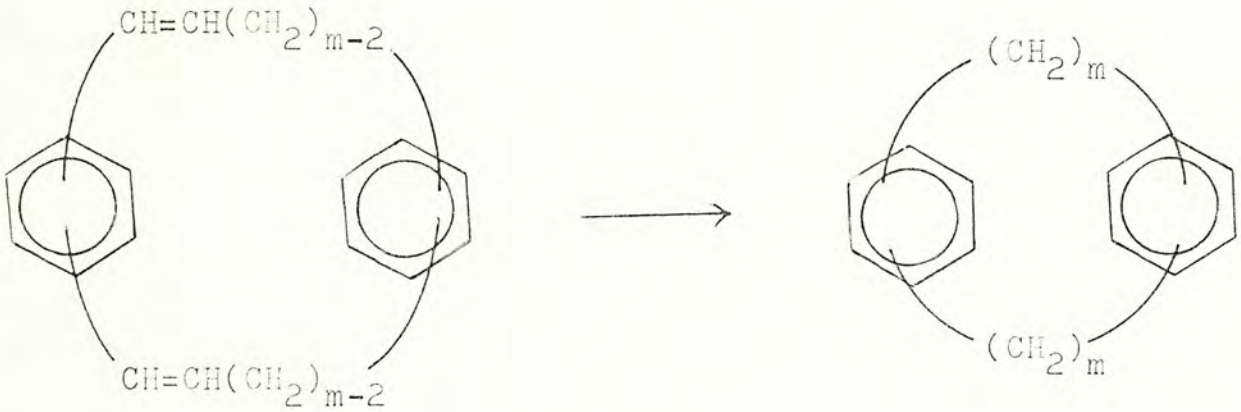


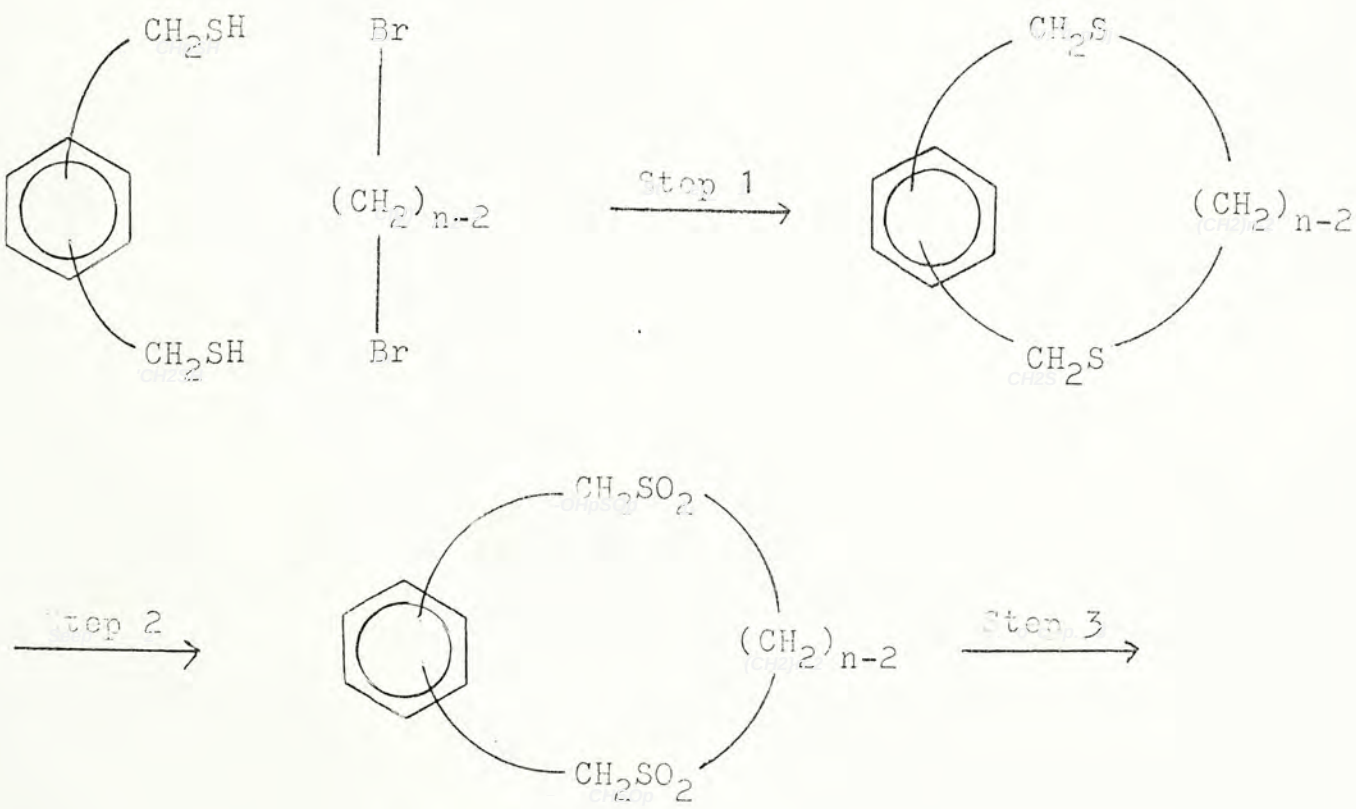
25

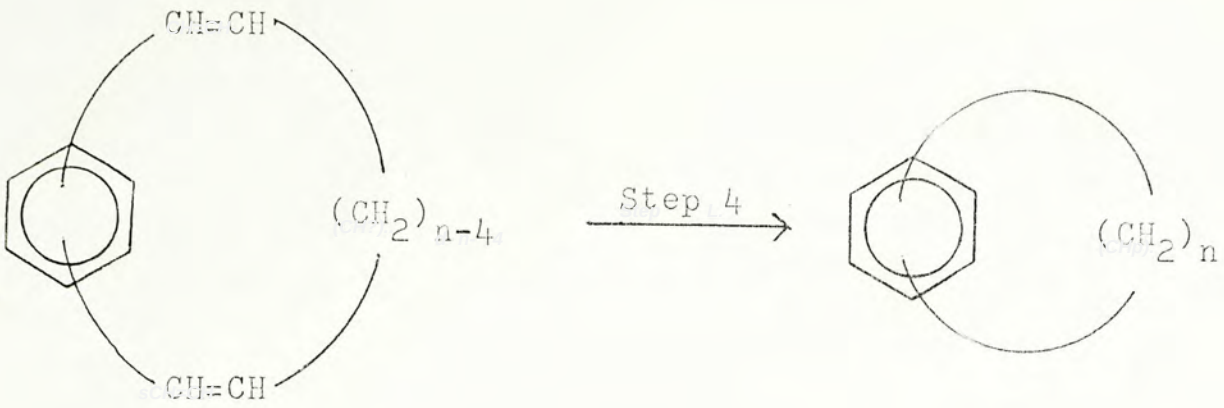
"one-flask" procedure into cyclophanedienes 20 and 25, respectively, in reasonable yields. Subsequent catalytic hydrogenation of 20 and 25 led to a variety of [n]cyclophanes and

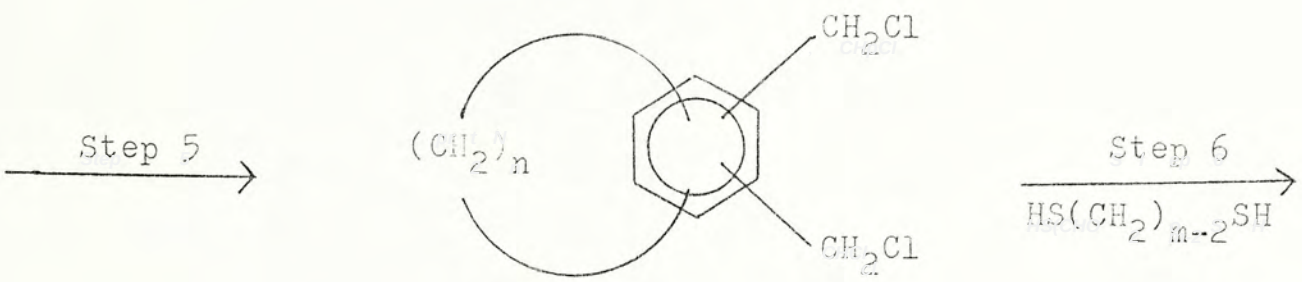
medium-sized [m.m]cyclophanes. Taking advantages of this knowledge, we selected to construct the second bridge of the [m][n]cyclophanes in a similar fashion, i.e., by applying the modified Ramberg-Bäcklund rearrangement on the bissulfones of 23.

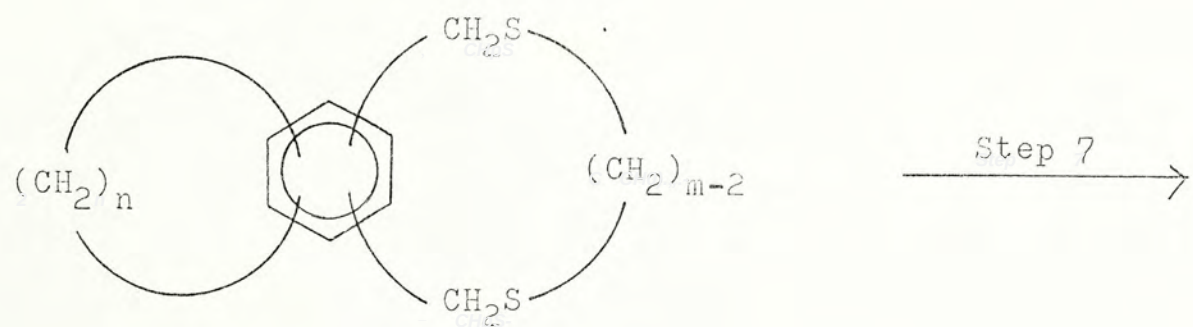
With the anticipation that compounds 23 would be easily accessible and on further assumption that the proposed sulfur extrusion step would not meet with unforeseeable complications, we began to undertake the synthesis of [m][n]cyclophanes by the reaction sequence as outlined in Scheme II.

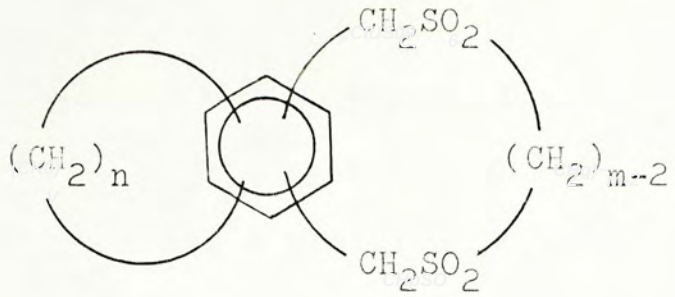
Scheme II. Projected Synthesis of [m][n]Cyclophanes



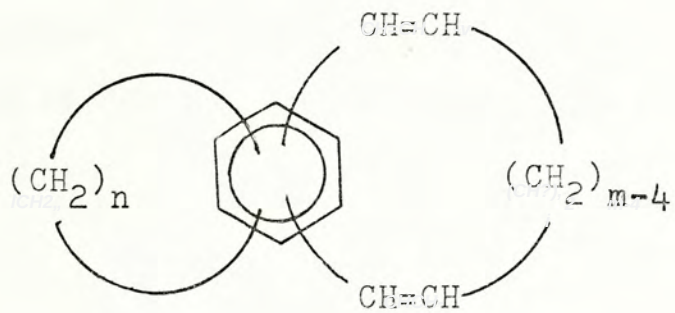

CH=CH
(CH2)n-4
CH=CH
Step 4
(CH2)n


Step 5
CH2Cl
(CH2)n
CH2Cl
Step 6
HS(CH2)m-2SH

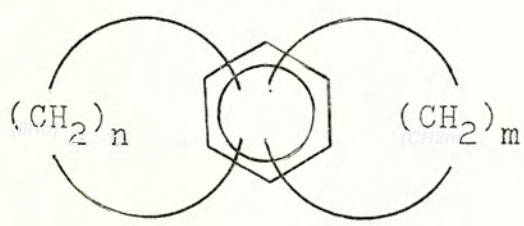

CH2S
(CH2)n
(CH2)m-2
CH2S
Step 7



Step 8 →

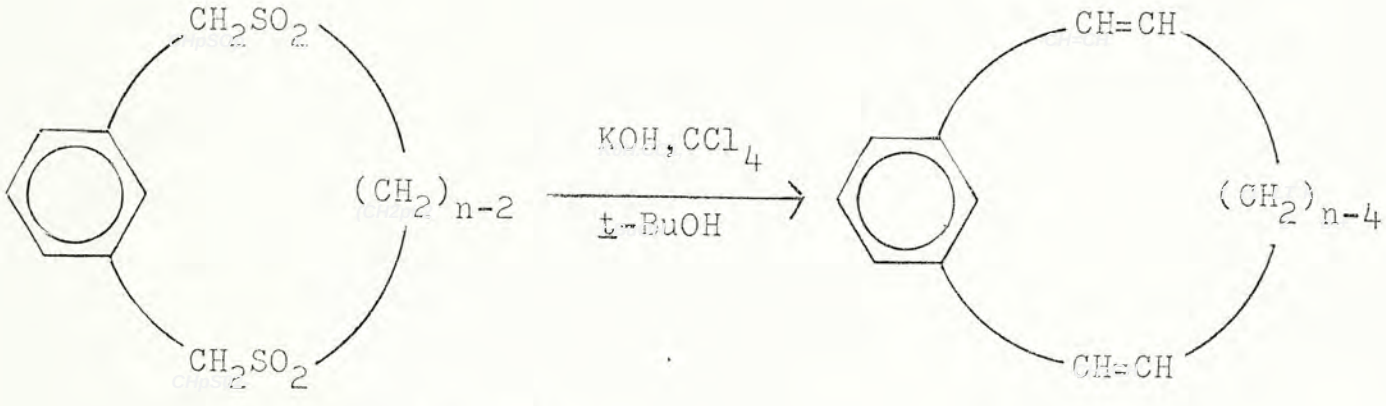


Step 9 →

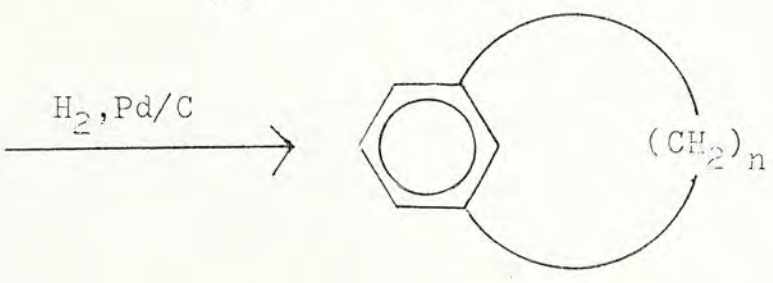


IV. RESULTS AND DISCUSSION

With the exception of Nakazaki's works[5], the synthesis of [m][n]cyclophanes was an area largely unexplored. Our objective was to devise a practical and hopefully flexible route to these systems. In order to put to test our projected synthetic scheme in a systematic manner, it was of primary importance that the key intermediates —— the [n]cyclophanes in Scheme II, be obtained in manageable quantities. Part of the solution was provided by the previous study of Li[6] in our laboratory. The yields of the [n]metacyclophanes 27, calculated on the basis of the corresponding dithiametacyclophane bissulfones 26, were



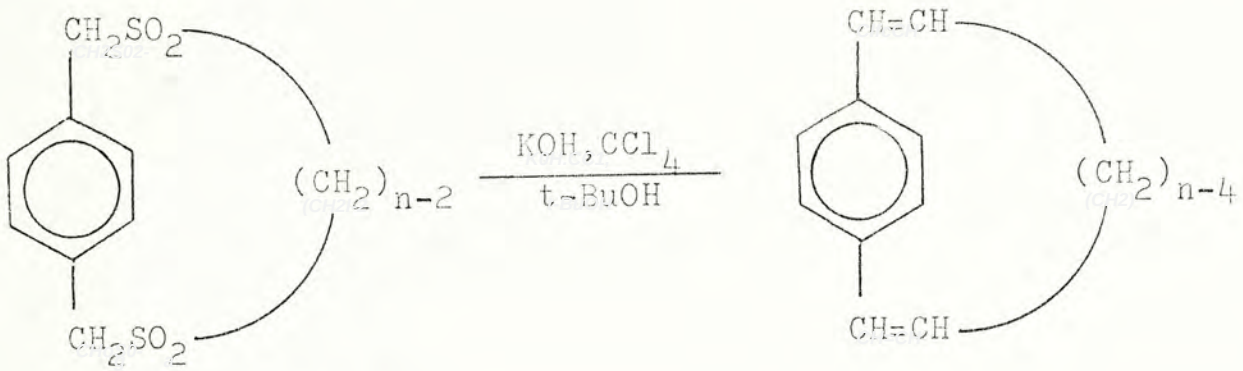
26 n= 12,13,14



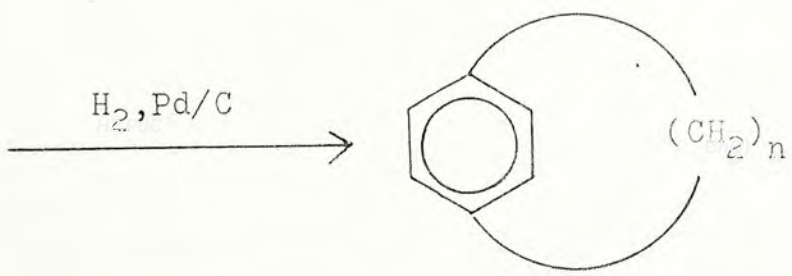
n= 12	41.5%
n= 13	60.7%
n= 14	41.6%

27

generally satisfactory and compared favorably with those obtained by more elaborate procedures[8,9,21]. Nevertheless, certain difficulties[6] were noted in the preparation of [n]-paracyclophanes 29. For examples, treatment of [n]paracyclophane bissulfones 28 with potassium hydroxide - carbon tetrachloride - t-butanol (the Meyers reagent[19,20]) followed by hydrogenation of the resulting paracyclophanedienes, gave only marginal yields of 29. Therefore, a major effort at the initial stage



28 n= 12, 14



n= 12 19.6%

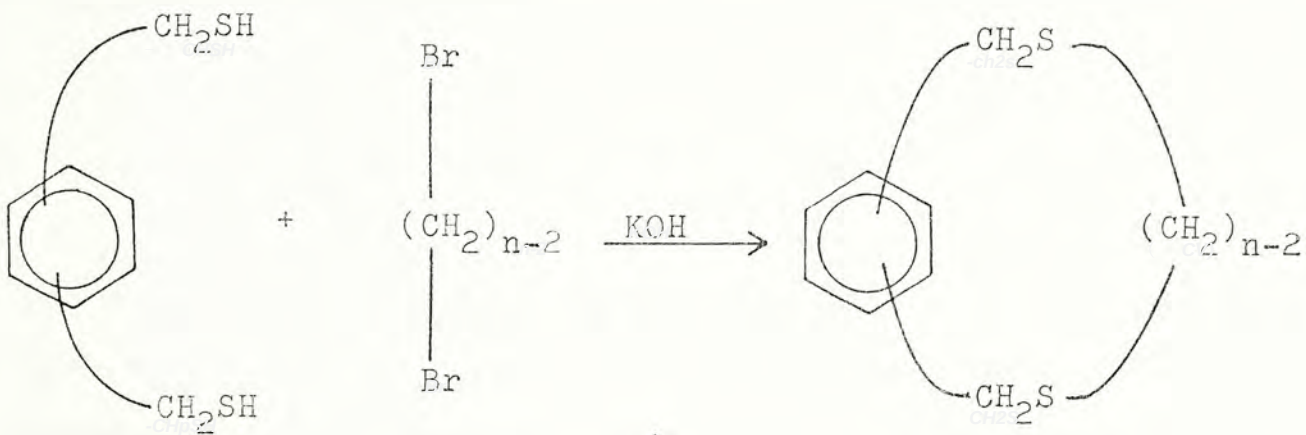
n= 14 21.0%

29

(Scheme II, Steps 1-4) of the present investigation was devoted to improve these yields. The second and the third stages involved the bischloromethylation of [n]cyclophanes (Scheme II, Step 5), and the construction of the second bridge (Scheme II, Steps 6-9), respectively.

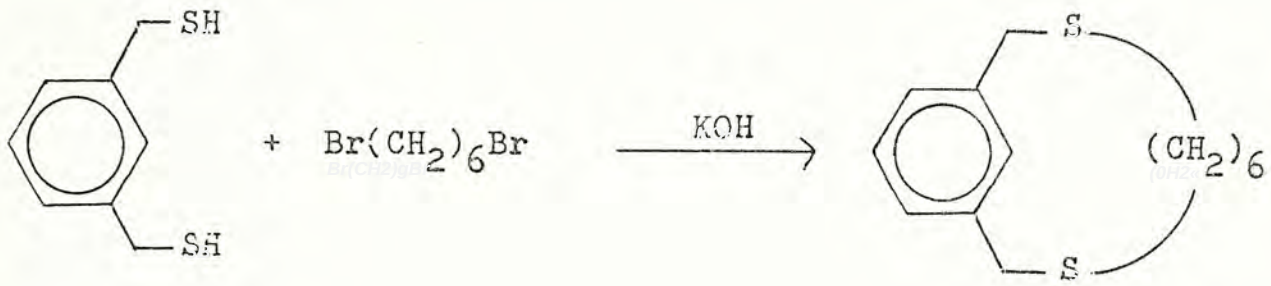
IV.1. Synthesis of [n]Cyclophanes

The cyclocoupling of bis(mercaptomethyl)benzene with α,ω-aliphatic dibromides proceeded smoothly to give dithiacyclophanes in remarkable yields considering the size of the



rings formed. These facile reactions further demonstrated the power of sulfur-mediated ring-closure reactions. The procedure was simple and required the addition of a solution of the dithiol and dibromide, under moderately high dilution, to a suit-

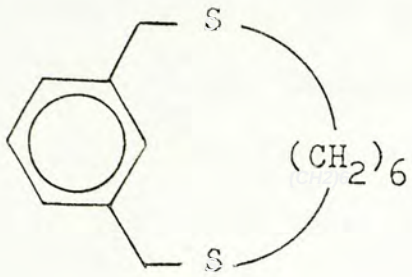
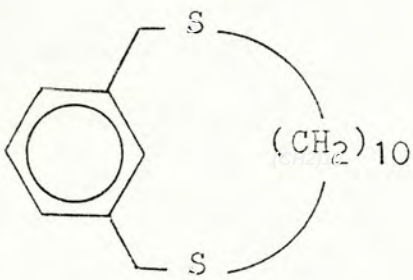
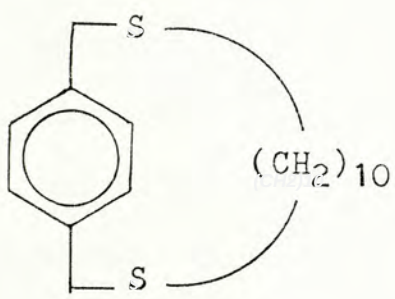
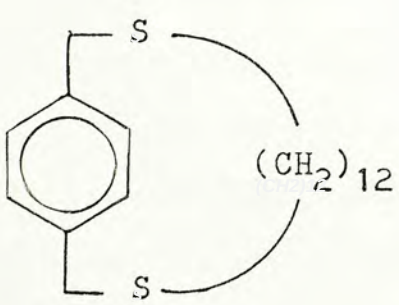
able solvent (usually benzene-ethanol) containing a slight excess of potassium hydroxide. Employing the convenient scale described below, it normally took two or three days, including isolation, to prepare six to seven grams of pure products. The preparation of 2,9-dithia[10]metacyclophane (30) from m-bis(mercaptomethyl)benzene and 1,6-dibromohexane is illustrative. A solution of 30 mmoles each of the dithiol



30

and dibromide in 500 ml of benzene was added dropwise over 30 h to a rapidly stirred solution of 7.5 g of potassium hydroxide in 1.2 l of 95% ethanol. Upon further stirring for 12 h, the solvent was removed in vacuo. The crude product was isolated by column chromatography to give pure 30 in 70.9% yield. Utilization of this simple procedure led to the four dithia[n]cyclophanes 30-33 listed in Chart I. The structures of these compounds were confirmed by nmr, ms, and

Chart I. Dithia[n]cyclophanes Prepared in This Study

Dithia[n]cyclophane	m.p. (°C)	% Yield
 30	65-66	70.9
 31	30-32	68.8
 32	43-44	71.3
 33	48-49	69.7

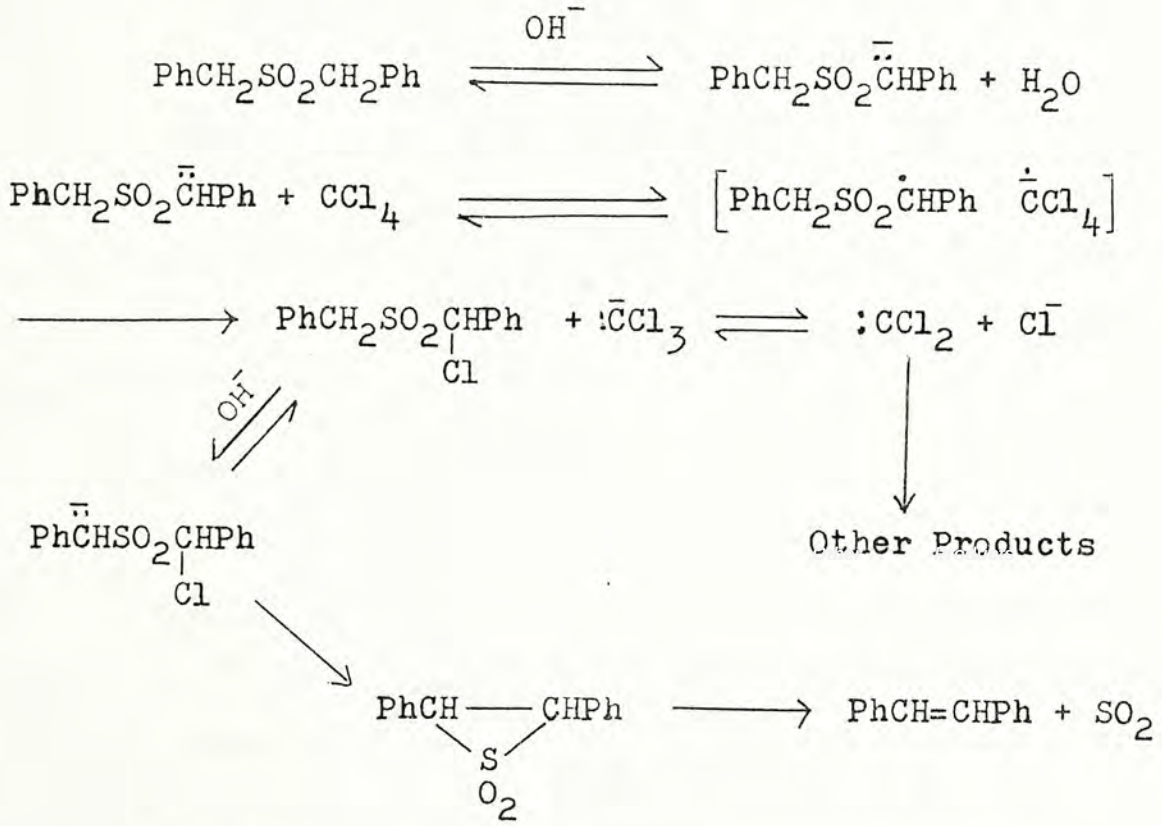
elemental analysis data. As a result, these valuable synthetic intermediates were reliably and routinely prepared.

According to the steps outlined in Scheme II, it was necessary to convert all the dithiacyclophanes listed in Chart I into the corresponding bissulfones prior to the execution of the Ramberg-Bäcklund rearrangement following Meyers' procedure. The desired oxidation could be readily accomplished either with hydrogen peroxide in acetic acid or with m-chloroperbenzoic acid in chloroform. However, the use of the former reagent was less time-consuming and allowed an easier work-up. It was thus by this oxidation dithiacyclophane bissulfones 34-37 (Chart II) were prepared. In most case, the yields were nearly quantitative.

In line with our projected synthetic scheme, each and every member of the series of dithiacyclophane bissulfones 34-37 listed in Chart II was subjected to Meyers' modification of the Ramberg-Bäcklund rearrangement. Treatment of the individual bissulfones 34-37 with the Meyers reagent under different conditions and for various durations did not bring about any appreciable improvement in the yields of cyclophanedienes 38-41 (Chart II). It was only after careful analysis of the nmr spectra did come to light the reason for these disappointing results.

At this point, it is worthwhile to give a brief discussion on the mechanism of the Meyers' modification of the Ramberg-Bäcklund rearrangement (the Meyers reaction). It

is well known that the reactions of the Meyers reagent with sulfones containing α-hydrogens lead initially to α-chlorosulfones which may be isolated or further transformed *in situ* into various types of products, among which olefins usually predominate. Extensive studies by Meyers' group[19,20] have provided convincing evidence to show that the chlorination step proceeds by a "radical-anion radical pair" complex as shown below using dibenzyl sulfone as an example. The



chlorosulfone generated in this manner proceeds by the normal course of the conventional Ramberg-Bäcklund rearrangement[22] to give stilbene. Concomitant to this

transformation is the generation of dichlorocarbene arising from trichlorocarbanion. In a large number of cases, extrusion of sulfur dioxide from α-chlorosulfones occurs considerably slower than dichlorocarbene consumption by solvent molecules or other reacting species, so that the Meyers reaction has found broad utility in olefin synthesis. However, in those cases where these two processes compete in comparable rates, a considerable degree of gem-dichlorocyclopropanation takes place on the olefins. Inspection of the nmr spectra of the crude products from the Meyers reaction of dithiacyclophane bissulfones 34-37 revealed that various extents of gem-dichlorocyclopropanation indeed took place in the cyclophanedienes 38-41. The outcome of the dichlorocarbene insertion process not only cut down the yields of the sought-after cyclophanedienes but also seriously complicated the isolation procedure.

To combat the afore-mentioned undesirable side-reaction, an obvious solution was to sweep out all the dichlorocarbenes prior to their invasion to the individual cyclophanediene. Accordingly, the Meyers reaction of each of the dithiacyclophane bissulfones 34-37 was conducted in the presence of cyclohexene which was added as a carbene scavenger. As a result of this measure, cyclophanedienes 38-41 were isolated in considerable better yields. The nmr spectra of these compounds indicated they were essentially free of their dichlorocarbene adducts but did not allow definite assignment to be made on

the geometric configuration of the olefinic double bonds. However, since isomeric purity is of no particular consequence in our synthetic scheme, these substances were used without further purification to avoid material loss. Hydrogenation of the cyclophanedienes 38-41 proceeded smoothly as expected to furnish the corresponding [n]cyclophanes 42-45. The structures of these important synthetic intermediates together with their yields and the corresponding precursors are shown in Chart II.

If due consideration is given to the fact that a double Ramberg-Bäcklund rearrangement is involved in each of the bissulfones listed in Chart II, the yields of the [n]cyclophanes obtained are indeed quite satisfactory. All the more gratifying is that the simple inclusion of cyclohexene in the Meyers reaction has led to such profitable results. With this measure, the yields for the metacyclophanes 42 and 43 were increased by one-fourth, and those for the paracyclophanes 44 and 45 were increased by nearly one-half. Furthermore, protected against the assault of dichlorocarbene, the cyclophanedienes 38-41 were isolated in considerable higher purity with relative ease. As a result, this procedure enabled us to secure, in a single run, gram quantities of the valuable intermediates 42-45.

Chart II. [n]Cyclophanes Prepared in This Study

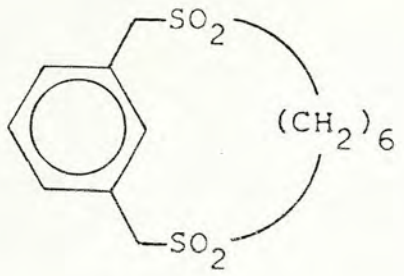
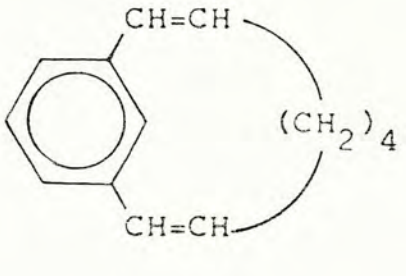
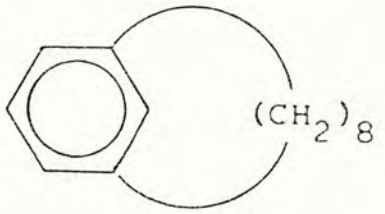
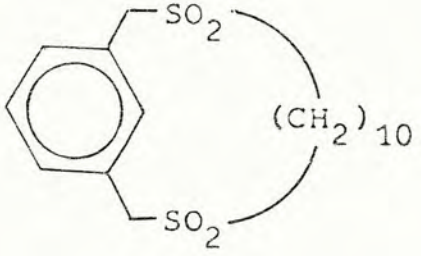
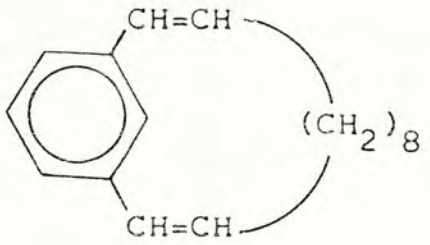
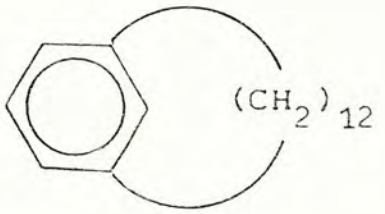
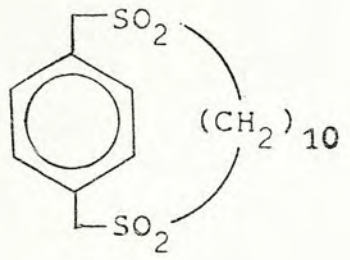
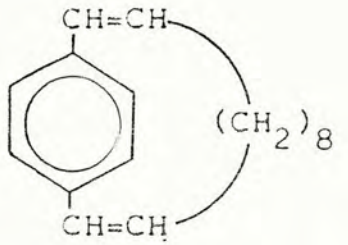
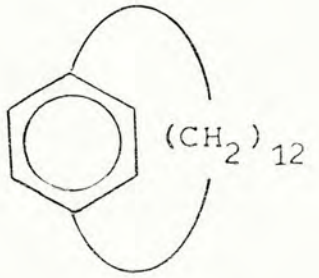
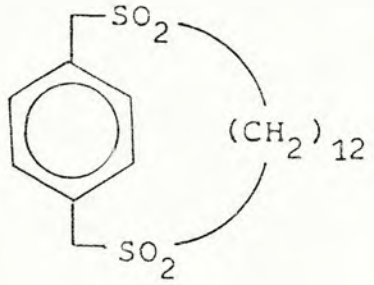
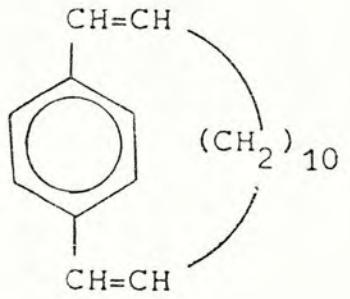
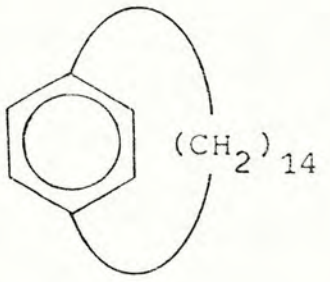
Dithiacyclophane Bissulfone Precursor	[n]Cyclophanediene Precursor	[n]Cyclophane	% Yield Based on Dithiacyclophane Bissulfones: Without Added Cyclohexene in The Meyers Rxn.	% Yield Based on Dithiacyclophane Bissulfones: With Added Cyclohexene in The Meyers Rxn.
 34	 38	 42	41.2	50.2
 35	 39	 43	41.5	55.3

Chart II. (Cont'd)

Dithiacyclophane Bissulfone Precursor	[n]Cyclophanediene Precursor	[n]Cyclophane	% Yield Based on Dithiacyclophane Bissulfones	
			Without Added Cyclohexene in The Meyers Rxn.	With Added Cyclohexene in The Meyers Rxn.
 36	 40	 44	19.6	28.1
 37	 41	 45	21.0	30.1

IV.2. Bischloromethylation of [n]Cyclophanes

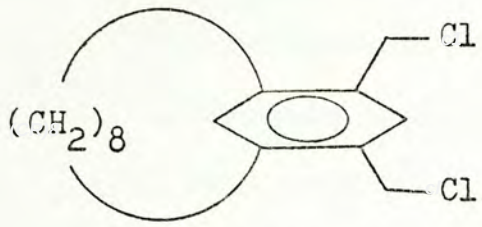
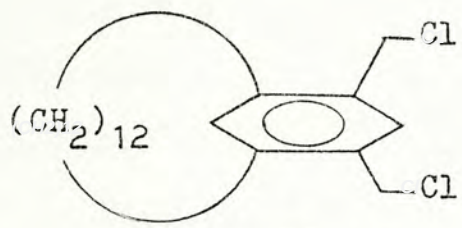
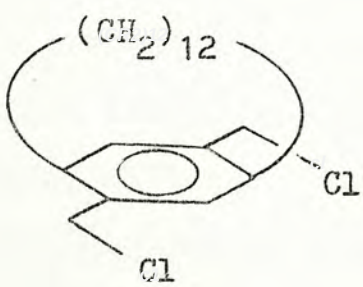
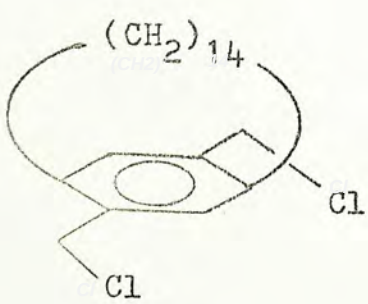
According to the synthetic plan outlined in Scheme II, the next stage was to introduce into the [n]cyclophanes on hand proper functionalities upon which the second aliphatic bridge was to be anchored. It was toward this goal that the bischloromethylation of [n]cyclophanes 42-45 was investigated extensively. At first, attempts to effect this transformation were made in the simplest possible fashion —— by treating each cyclophane conventionally with a solution of 38% aqueous formalin and 12 M hydrochloric acid at various temperatures up to 90° and for different durations up to 48 h. However, none of these conditions was effective and in every instance was recovered the starting material unreacted. Since the cyclophane substrates were insoluble in an aqueous medium, it was thought that the difficulty might have arisen from the heterogeneous nature of the reaction. Attracted by the advantages of phase-transfer catalysis, some of the experiments were repeated with the inclusion of several quaternary ammonium chlorides. Much to our disappointment, these attempts were also unfruitful.

Other attempts were made to effect the intended bischloromethylation in non-aqueous solvents so that homogeneity was reasonably assured. For examples, the reaction of 42 was conducted in a refluxing solution of glacial acetic acid saturated with paraformaldehyde, into which a constant stream

of dry hydrogen chloride was passed. The results, however, were erratic. After about 12 h under this condition, the reaction seemed to reach a stationary state resulting in the formation of a mixture consisting of the starting material, the monochloromethylated product, and the bischloromethylated product, of which the first-named was by far the predominant component. Increasing the reaction temperature by replacing acetic acid with propanoic acid as solvent only complicated matters further by the occurrence of dealkylation of the methylene bridge.

As a result of these disappointing observations, our attention was turned to more recently developed chloromethylation procedures. Of several possible alternatives[23] contemplated, the use of chloromethyl methyl ether - stannic chloride was at once found to be highly satisfactory. The procedure described as follows for the preparation of 10,12-bis(chloromethyl)[8]metacyclophane (46) amply illustrates the synthetic value of this reagent for the bischloromethylation of [n]cyclophanes. To a well stirred and drying-tube protected solution containing 0.5 g of [8]metacyclophane (42), 3 ml of chloromethyl methyl ether and 10 ml of carbon disulfide was added dropwise 2 ml of stannic chloride over a period of ~10 min. Upon further stirring at room-temperature for 15 h, the reaction mixture was poured into ice-water. Extraction with dichloromethane followed by column chromatography afforded

Chart III. Bis(chloromethyl)[n]cyclophanes Prepared by The use of Chloromethyl Methyl Ether - Stannic Chloride in Carbon Disulfide

Bis(chloromethyl)[n]cyclophane	% Yield
 46	73.8
 47	75.8
 48	70.5
 49	72.7

pure bischloromethylated product 46 in 73.8% yield. Utilization of this procedure provided the other three desired bischloromethylated [n]cyclophanes 47-49. The structures of these substances together with their yields are listed in Chart III.

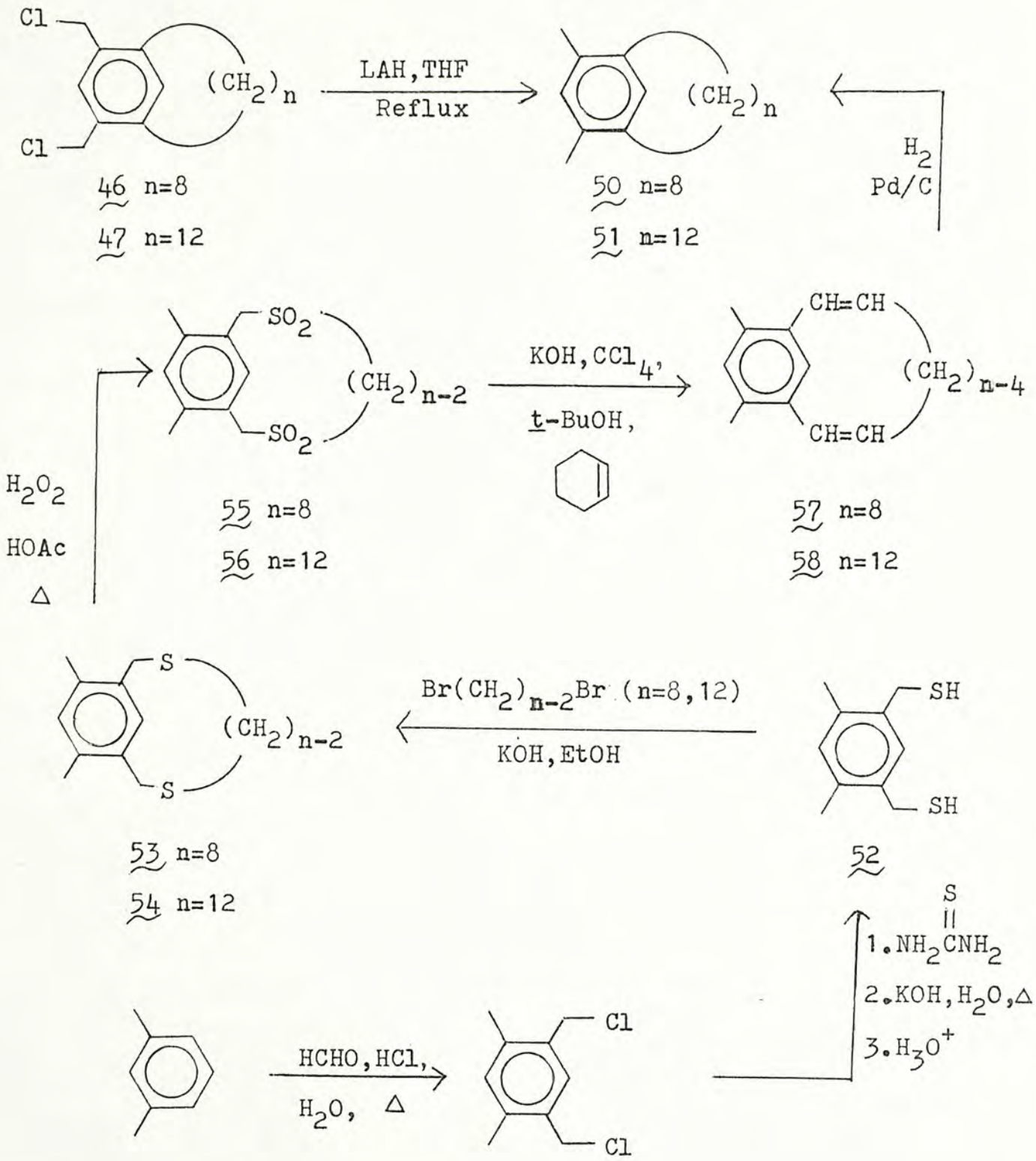
The orientations of the chloromethyl substituents in each of the compounds listed in Chart III raised little skepticism for two reasons: in the first place, the nmr spectra of these compounds were in complete agreement with the structures assigned, and, secondly, the directive effects of the methylene bridges in the strain-free [n]meta- and [n]paracyclophanes were not expected to be any different from those of the methyl groups in m- and p-xylenes, respectively. Nevertheless, more vigorous independent chemical proofs were needed to confirmed structures 46-49 unequivocally.

The approach (Schemes III and IV) we adopted to secure these structural proofs involved the reduction of bischloromethylated [n]cyclophanes 46-49 into the corresponding dimethyl[n]cyclophanes which were then compared with the authentic samples synthesized unambiguously. Thus as showned in Scheme III, 10,12-bis(chloromethyl)[8]metacyclophane (46) and 14,16-bis(chloromethyl)[12]metacyclophane (47) were individually reduced by lithium aluminum hydride to 10,12-dimethyl[8]metacyclophane (50) and 14,16-dimethyl[12]metacyclophane (51). Compounds 50 and 51 were then independently synthesized in a six-steps sequence tracing to m-xylene and pivoting on the key

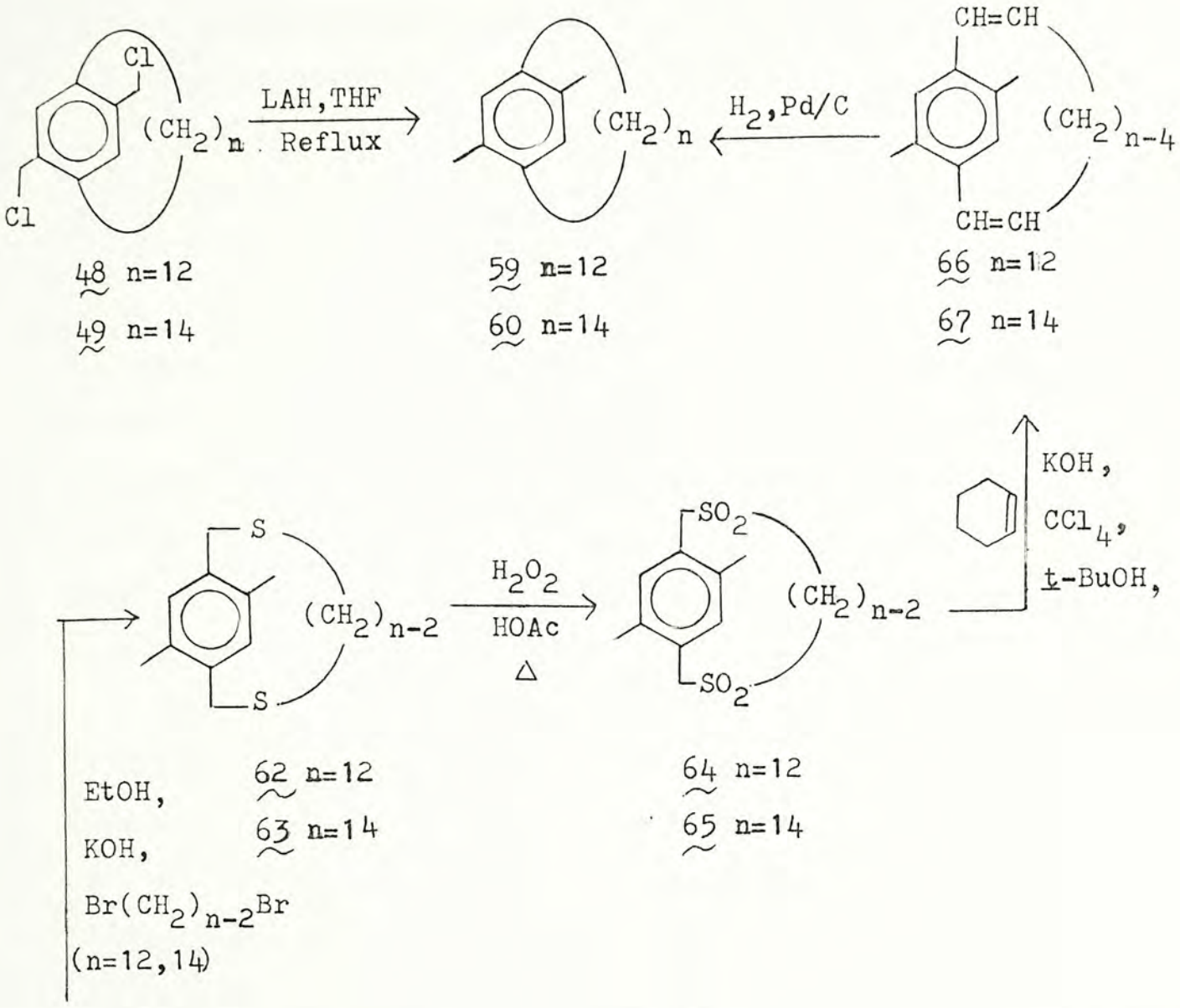
intermediate 4,6-bis(mercaptomethyl)-m-xyleme (52). The two-steps preparation of dithiol 52 from m-xylene via 4,6-bis(chloromethyl)-m-xylene[10] was straightforward and uneventful. Cyclocoupling of 52 with 1,6-dibromohexane and with 1,10-dibromodecane gave 12,14-dimethyl-2,9-dithia[10]metacyclophane (53) and 16,18-dimethyl-2,13-dithia[14]metacyclophane (54), respectively. Oxidation of dithiacyclophanes 53 and 54 with hydrogen peroxide led to the corresponding dithiacyclophane bissulfones 55 and 56. Extrusion of sulfur dioxide from 55 and 56 was individually executed by the previously discussed Meyers reaction in the presence of cyclohexene. Hydrogenation of the resulting cyclophanedienes 57 and 58 led to the corresponding dimethyl[8]- and dimethyl[12]metacyclophanes 50 and 51, The identicalness of the nmr and ir spectra of the respective sets of samples of 50 and 51, obtained from the two independent routes described above, afforded complete proofs for the structures of the dichlorides 46 and 47.

Structural proofs for 14,17-bis(chloromethyl)[12]paracyclophane (48) and 16,19-bis(chloromethyl)[14]paracyclophane (49) were obtained in a similar manner from the two converging paths outlined in Scheme IV. As expected, dechlorination of 48 and 49 was accomplished by using lithium aluminum hydride to give 14,17-dimethyl[12]paracyclophane (59) and 16,19-dimethyl[14]paracyclophane (60), respectively. The dimethylcyclophanes 59 and 60 were independently synthesized in

Scheme III. Structural Proofs for 10,12-Bis(chloromethyl)[8]-metacyclophane (46) and 14,16-Bis(chloromethyl)-[12]metacyclophane (47)



Scheme IV. Structural Proofs for 14,17-Bis(chloromethyl)[12]-paracyclophane (48) and 16,19-Bis(chloromethyl)-[14]paracyclophane (49)



48 n=12
49 n=14

59 n=12
60 n=14

66 n=12
67 n=14

62 n=12
63 n=14

64 n=12
65 n=14

61

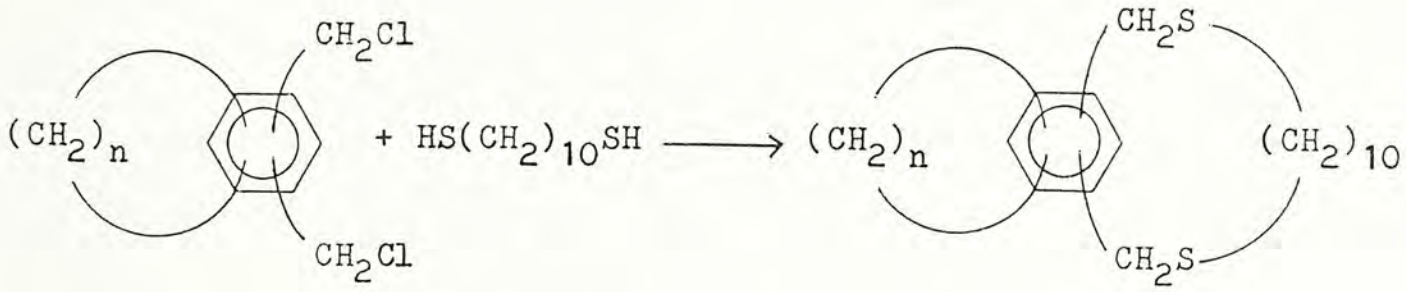
six-steps starting from p-xylene. Bischloromethylation of p-xylene[10] followed by reaction with thiourea gave 2,5-bis(mercaptomethyl)-p-xylene (61) which was cyclocoupled with 1,10-dibromodecane and with 1,12-dibromododecane to yield the respective 16,19-dimethyl-2,13-dithia[14]paracyclophane (62) and 18,21-dimethyl-2,15-dithia[16]paracyclophane (63). Oxidation of 62 and 63 followed by the sulfur dioxide extrusion from the resulting dithiacyclophane bissulfones 64 and 65 by the Meyers procedure in the presence of added cyclohexene led to the cyclophanedienes 66 and 67, each of which was presumably an isomeric mixture. Hydrogenation of 66 and 67 provided the corresponding reference samples of 59 and 60, which were identical in all respects to their counterparts originating from 48 and 49.

The reaction sequences outlined in Schemes III and IV not only unambiguously established the structures of dichlorides 46-49 but also further demonstrated the usefulness of the Meyers reaction in the synthesis of strain-free cyclophanes. With the orientations of chloromethyl groups in 46-49 thus confirmed, we were able to proceed meaningfully with the assembling of the second bridges in the targeted [m][m]cyclophanes. It was by this strategy that we have been able to make available, for the first time, two [m][n]-metacyclophanes and the two [m][n]paracyclophanes described below.

IV.3. Synthesis of [m][n]Cyclophanes

It is all too clear from our synthetic plan presented in the previous section that our approach to the [m][n]cyclophanes revolves on the simple idea of putting into use sulfur-mediated cyclocoupling reactions in conjunction with the Meyers reaction. The fruitful results up to the stage of the bis(chloromethyl)[n]cyclophanes 46-49 provided further stimulus to continue investigation along this line.

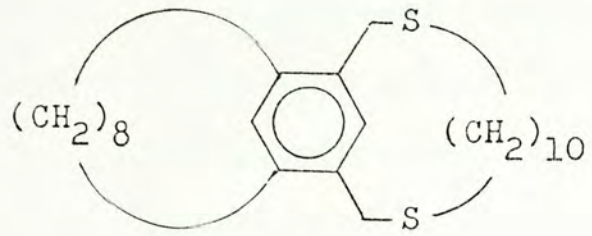
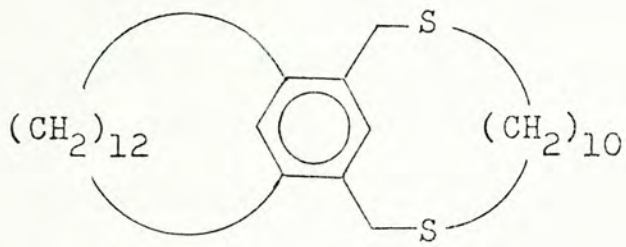
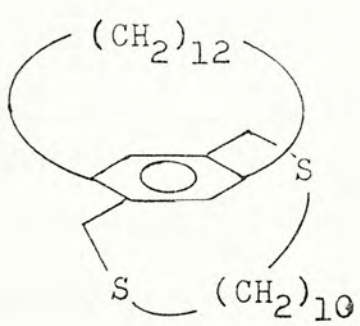
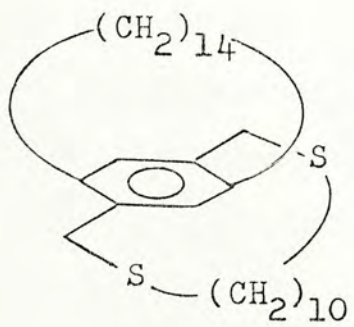
In order to minimize material loss, the dichlorides 46-49 were not converted into the corresponding dithiols, but instead were each cyclocoupled with 1,10-decanedithiol.



The choice of this particular alkanedithiol was made purely for economic reasons. It could be conveniently prepared from 1,10-dibromodecane which was one of the less expensive long-chain aliphatic dibromides available.

The cyclocoupling of individual dichlorides 46-49 with 1,10-decanedithiol was best carried out by slow addition over 24 h of a solution of 1.1 mmol each of the co-reactants in

Chart IV. [14][n]Dithiacyclophanes Prepared in This Study

	m.p. (°C)	% Yield
 68	85-86	75.4
 69	106-108	70.3
 70	50-52	69.8
 71	128-130	73.6

200 ml of benzene to a vigorously stirred solution of 300 ml of ethanol containing 2.5 g of potassium hydroxide. On work-up by extraction with light petroleum ether (50-75°C), and on separation of the extracted crude materials by column chromatography furnished the array of [14][n]dithiacyclophanes 68-71 listed in Chart IV. The yields obtained for these compounds were again remarkable.

Oxidation of the [14][n]dithiacyclophanes 68-71 was effected cleanly with m-chloroperbenzoic acid in chloroform. The corresponding [14][n]dithiacyclophane bissulfones 72-75 (Chart V), which were obtained in almost quantitative yields, were individually subjected to the Meyers reaction with cyclohexene added to safeguard against possible dichlorocyclopropanation on the desired ring-contracted [12][n]cyclophanedienes 76-79. These cyclophanedienes were obtained as viscous oils, and in some cases were perhaps not isomerically pure. As it was unnecessary to further separate them into pure isomeric components, they were used in the final step as such. Our synthetic scheme was completed by catalytic hydrogenation of the [14][n]cyclophanedienes 76-79.

The structures of the four [m][n]cyclophanes, namely, [8][12]metacyclophane (80), [12][12]metacyclophane (81), [12][12]paracyclophane (82), and [12][14]paracyclophane (83), successfully synthesized in the present investigation are shown in Chart V, together with those of their corresponding immediate progenitors. All the [m][n]cyclophanes obtained were fully characterized by nmr, ms, microanalysis, and/or precise molecular mass data.

Chart V . [m] [n] Cyclophanes Prepared in This Study

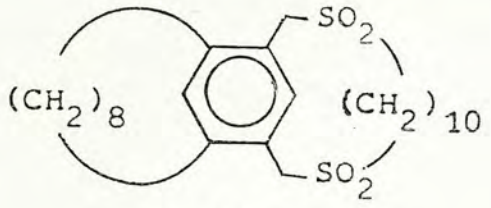
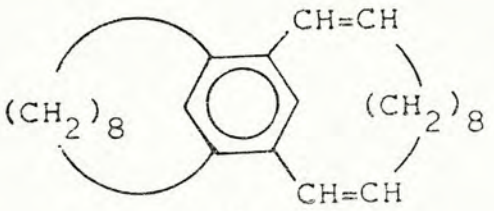
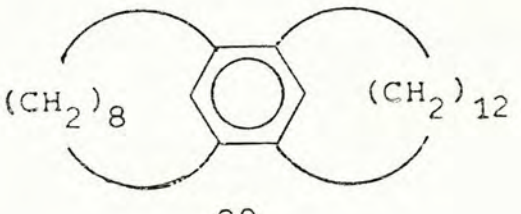
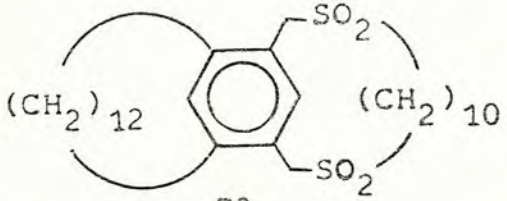
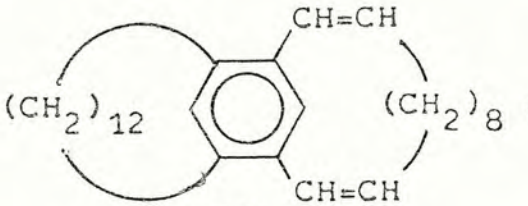
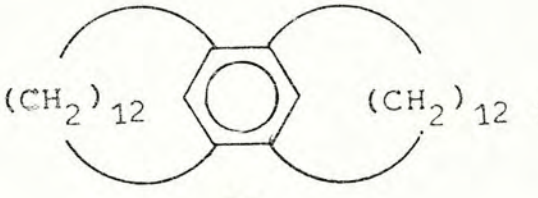
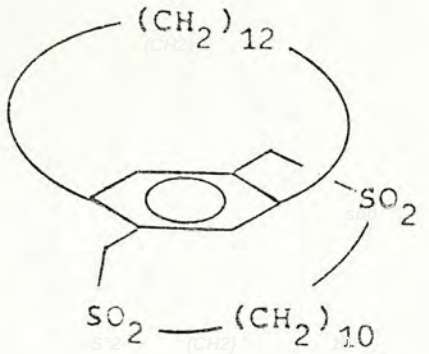
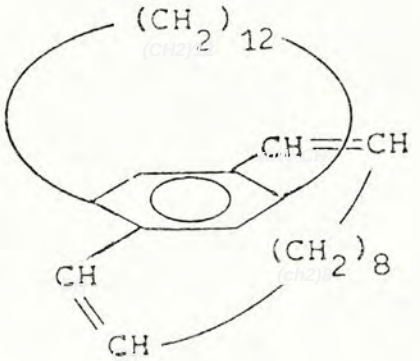
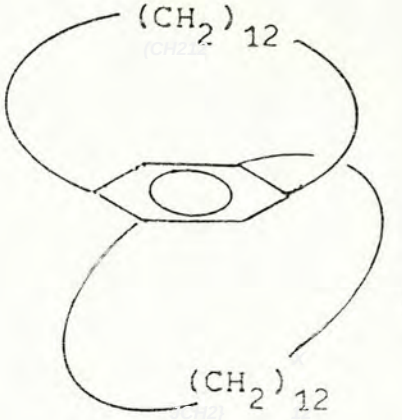
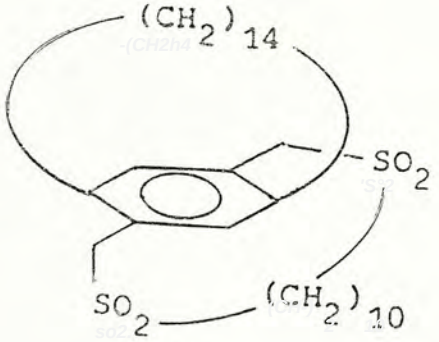
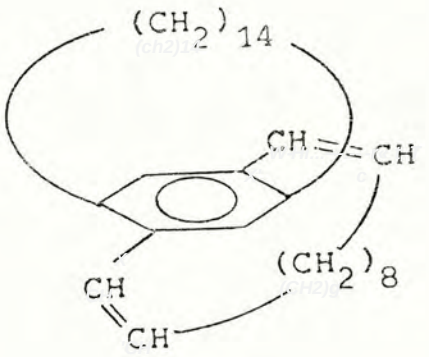
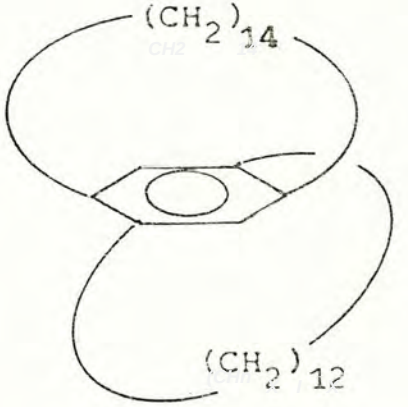
[m+2] [n] Dithiacyclohane Bissulfone Precursor	[m] [n] Cyclophanediene Precursor	[m] [n] Cyclophane	m.p. (°C)	% Yield Based on Bissulfone
 72	 76	 80	55-57	50.4
 73	 77	 81	160-162	54.7

Chart V. (Cont'd)

[m+2] [n] Dithiacyclophane Bissulfone Precursor	[m] [n] Cyclophanediene Precursor	[m] [n] Cyclophane	m.p. (°C)	% Yield Based on Bissulfone
 74	 78	 82	92-94	30.6
 75	 79	 83	69-71	29.8

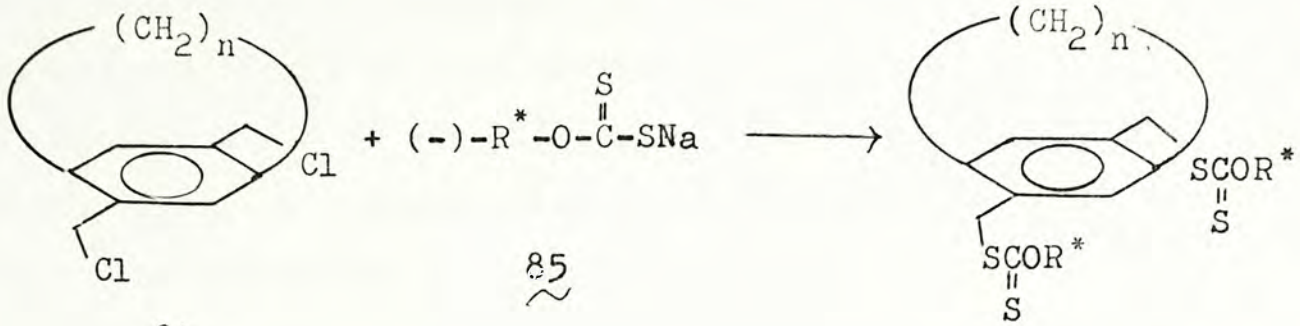
V. CONCLUSION AND OUTLOOK

The combination of sulfur-mediated cyclocoupling reactions and the Meyers reaction offers an attractive route to [m][n]cyclophanes, which is amenable to structural variations in respect of the length of both methylene bridges as well as the manner in which the benzene ring is anchored. The successful preparation of the four hitherto unknown [m][n]cyclophanes 80-83 amply demonstrates the flexibility of this methodology. The nine-steps sequence described in this Thesis requires neither exotic reagents nor complicated operations. The overall yields, ranging from ~3% for the [m][n]paracyclophanes 82-83 to ~10% for the [m][n]meta-cyclophanes 80-81, are nevertheless adequate to provide reasonable quantities of this interesting class of hydrocarbons whose chemistry awaits exploration.

By proper manipulation of the bis(chloromethyl)[n]para-cyclophanes of the general type 84, it is possible to modify the present scheme to suit the preparation of optically active [m][n]paracyclophanes. The steps formulated in Scheme V are worthy of consideration.

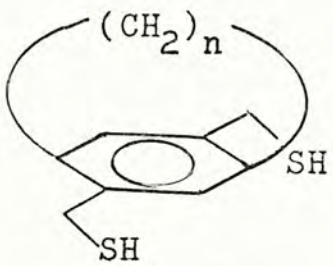
Reaction of (±)- 84 with (-)-sodium o-menthyl dithio-carbonate[24] (85) would lead to a mixture of diastereomeric bisxanthogenic esters 86. Resolution of 86 by fractional crystallization followed by decomposition with morpholine of the resulting diastereomerically pure xanthogenic esters

Scheme V. Proposed Route to Optically Active [m][n]Paracyclophanes



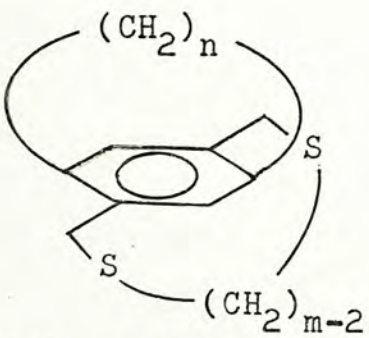
84 85 Diastereomers 86

1. Resolution
2. Morpholinolysis



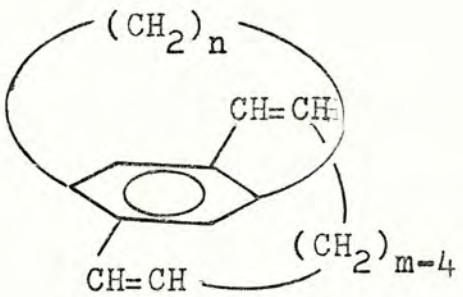
(+)- or (-)- 87

$Br(CH_2)_{m-2}Br$



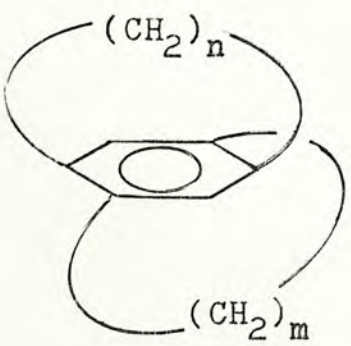
(+)- or (-)- 88

1. Oxidation
2. Meyers Rxn.

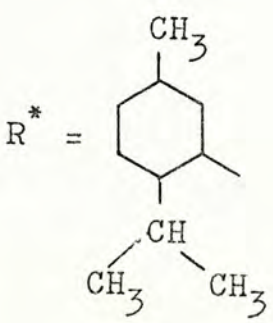


(+)- or (-)- 89

H_2, Pd/C



(+)- or (-)- 90



would give rise to optically active bis(mercaptomethyl)[n]paracyclophanes 87. Cyclocoupling of 87 with appropriate α,ω-dibromoalkanes would lead to the formation of optically active [m+2][n]dithiaparacyclophanes 88. Conversion of 88 into the bissulfones which, on ring contraction by the Meyers reaction and hydrogenation of the anticipated [m][n]paracyclophanedienes 89 would provide a ready entry to various optically active [m][n]paracyclophanes 90.

A great deal of fascinating new chemistry can be developed from the methodology presented in this Thesis. Further efforts will surely be exciting and richly rewarding.

VI. EXPERIMENTAL

Melting points were measured on a Koefler hot stage and are reported uncorrected. Elemental analyses were performed by Australian Mircoanalytical Service, Port Melbourne, Victoria, Australia. Nuclear magnetic resonance spectra were recorded on a JEOL 60-HL instrument using tetramethylsilane as an internal standard. Mass spectra were determined using a VG Micromass 7070F instrument.

2,9-Dithia[10]metacyclophane (30)

To a vigorously stirred solution of 7.5 g of potassium hydroxide in 1.2 l of 95% ethanol at room-temperature was added dropwise a solution of 7.32 g (30 mmol) of 1,6-dibromohexane and 5.10 g (30 mmol) of 1,3-bis(mercaptomethyl)benzene in 500 ml of benzene over a period of 30 h. Upon further stirring for 12 h, the solvent was evaporated *in vacuo*. To the residue was added 500 ml of water, and the resulting aqueous suspension was repeatedly extracted with dichloromethane. The combined extracts were washed successively with brine and water, dried over anhydrous magnesium sulfate and evaporated to give a yellow liquid which was taken up in *ca* 8 ml of benzene and chromatographed over silica gel (E. Merck 7733). The fraction eluted with petroleum ether (50-75°C) - benzene (3:1) on evaporation afforded 5.36 g (70.9%) of a white solid. Recrystallization of this substance from *n*-hexane gave analytically pure 2,9-dithia[10]metacyclophane (30) as colorless

needles: m.p. 65-66°C; nmr (CCl_4) δ ppm 0.85-140 (unresolved broad peak, 8H, $-CH_2-$ at 4-7 positions), 2.20-2.45 (t, J=6Hz, 4H, $-CH_2-$ at 3 and 8 positions), 3.63 (s, 4H, $-CH_2-$ at 1 and 10 positions), 7.20-7.43 (m, 4H, ArH); ms (70eV) m/e 252 (M^+).
Anal.Calcd for $C_{14}H_{20}S_2$: 66.61%; H, 7.99%; S, 25.40%
Found: C, 66.68%; H, 7.83%; S, 25.20%.

2,13-Dithia[14]metacyclophane (31)

In the manner described for the preparation of dithiacyclophane 30 , 9.00 g (30 mmol) of 1,10-dibromodecane and 5.10 g (30 mmol) of 1,3-bis(mercaptomethyl)benzene were cyclocoupled in the presence of potassium hydroxide to give 6.36 g (68.8%) of dithiacyclophane[6] (31) as white solid: m.p. 30-32°C; nmr (CCl_4) δ ppm 1.00-1.80 (unresolved broad peak, 16H, $-CH_2-$ at 4-11 positions), 2.20-2.48 (t, J=6Hz, 4H, $-CH_2-$ at 3 and 12 positions), 3.60 (s, 4H, $-CH_2-$ at 1 and 14 positions), 7.08-7.25 (m, 4H, ArH).
Anal.Calcd for $C_{18}H_{28}S_2$: m/e 308.1632. Found: 308.1638.

2,13-Dithia[14]paracyclophane (32)

To a vigorously stirred solution of 7.5 g of potassium hydroxide at room-temperature was added dropwise a solution of 9.00 g (30 mmol) of 1,10-dibromodecane and 5.10 g (30 mmol) of 1,4-bis(mercaptomethyl)benzene in 500 ml of benzene over a period of 30 h. Upon further stirring for 12 h, the solvent was evaporated *in vacuo*. To the residue was added 500 ml of water, and the resulting aqueous suspension was repeatedly extracted with dichloromethane. The combined extracts were washed successively with brine and water, dried over anhydrous

magnesium sulfate and evaporated to give a yellow liquid which was taken up in ca 5 ml of benzene and chromatographed over silica gel (E. Merck 7733). The fraction eluted with petroleum ether (50-75°C) - benzene (3:1) on evaporation afforded 6.59 g (71.3%) of essentially pure 2,13-dithia[14]paracyclophane (32). Recrystallization of this material from ethanol provided an analytically pure sample as colorless needles : m.p. 43-44°C; nmr (CCl_4) δ ppm 0.72-1.70 (unresolved broad peak, 16H, non-benzylic $-CH_2-$ at 4-11 positions), 2.00-2.34 (t, J=6Hz, 4H, $-CH_2-$ at 3 and 12 positions), 3.60 (s, 4H, $ArCH_2S-$), 7.25 (s, 4H, ArH); ms (70eV) m/e 308 (M^+).

Anal. Calcd for $C_{18}H_{28}S_2$: C, 70.07%; H, 9.15%; S, 20.78%. Found: C, 69.90%; H, 8.95%; S, 20.60%.

2,15-Dithia[16]paracyclophane (33)

In the manner described for the preparation of dithiacyclophane 32 , 9.84 g (30 mmol) of 1,12-dibromododecane and 5.10 g (30 mmol) of 1,4-bis(mercaptomethyl)benzene were cyclocoupled in the presence of potassium hydroxide to give 7.03 g (69.7%) of essentially pure 2,15-dithia[16]paracyclophane (33), as a white solid. Recrystallization of this substance from ethanol afforded analytically pure 33 as colorless leaflets : m.p. 48-49°C; nmr (CCl_4) δ ppm 1.06-1.72 (unresolved broad peak, 20H, non-benzylic $-CH_2-$ at 4-13 positions), 2.06-2.37 (t, J=6Hz, 4H, $-CH_2-$ at 3 and 14 positions), 3.60 (s, 4H, $ArCH_2S-$), 7.25 (s, 4H, ArH); ms (70eV) m/e 336 (M^+).

Anal. Calcd for $C_{20}H_{32}S_2$: C, 71.36%; H, 9.58%; S, 19.04%. Found: C, 71.15%; H, 9.61%; S, 18.70%.

2,9-Dithia-2,2,9,9-tetraoxo[10]metacyclophane (34)

A mixture of 5.04 g (20 mmol) of 2,9-dithia[10]metacyclophane (30), 40 ml of glacial acetic acid, and 18 ml of 30% of hydrogen peroxide was heated with stirring at 100°C for 4 h. On refrigeration overnight, the precipitate formed was filtered off, washed successively with 5% sodium hydroxide and water, and dried at 80°C to afford 6.15 g (97.3%) of bissulfone 34 as white powder. Recrystallization of this substance from acetone gave analytically pure 34 as colorless prisms : m.p. 240-242°C; nmr (TFA) δ ppm 0.72-1.90 (unresolved broad peak, 8H, non-benzylic $-CH_2-$ at 4-7 positions), 2.60-3.52 (unresolved t, 4H, $-CH_2-$ at 3 and 8 positions), 4.61 (s, 4H, $ArCH_2SO_2-$), 7.50-7.75 (m, 4H, ArH); ms (70 eV) m/e 316 (M^+).

Anal. Calcd for $C_{14}H_{20}S_2O_4$: C, 53.14%; H, 6.37%; S, 20.26%. Found: C, 53.26%; H, 6.53%; S, 20.50%.

2,13-Dithia-2,2,13,13-tetraoxo [14]metacyclophane (35)

In the manner described for the preparation of bissulfone 34, 4.62 g (15mmol) of 2,13-dithia[14]metacyclophane (31) was oxidized with hydrogen peroxide to give 5.16 g (92.5%) of white powder. Recrystallization of this substance from acetone afforded analytically pure 2,13-dithia-2,2,13,13-tetraoxo[14]-metacyclophane (35) as colorless prisms: 204-206°C; nmr (TFA) δ ppm 0.80-2.14 (unresolved broad peak, 16H, non-benzylic $-CH_2-$ at 4-11 positions), 3.05-3.30 (t, J=6Hz, 4H, $-CH_2-$ at 3 and 12 positions), 4.62 (s, 4H, $ArCH_2SO_2-$), 7.64 (s, 4H, ArH); ms

(70eV) m/e 372 (M^+).

Anal. Calcd for $C_{18}H_{28}S_2O_4$: C, 58.03%; H, 7.57%; S, 17.17%. Found: C, 57.97%; H, 7.58%; S, 17.10%.

2,13-Dithia-2,2,13,13-tetraoxo[14]paracyclophane (36)

A mixture of 4.62 g (15 mmol) of 2,13-dithia[14]paracyclophane (32), 40 ml of glacial acetic acid, and 18 ml of 30% aqueous hydrogen peroxide was heated with stirring at 100°C for 4 h. On refrigeration overnight, the precipitate formed was filtered off, washed successively with 5% sodium hydroxide and water, and dried at 80°C to afford 5.32 g (95.3%) of bissulfone 36 as white powder. Recrystallization of this substance from acetone afforded an analytically pure sample as needles : m.p. 253-255°C; nmr (TFA) δ ppm 0.94-2.25 (unresolved broad peak, 16H, non-benzylic $-CH_2-$ at 4-11 positions), 2.86-3.30 (t, J=6Hz, 4H, $-CH_2-$ at 3 and 12 positions), 4.62 (s, 4H, $ArCH_2SO_2-$), 7.64 (s, 4H, ArH); ms (70 eV) m/e 372 (M^+).

Anal. Calcd for $C_{18}H_{28}S_2O_4$: C, 58.03%; H, 7.57%; S, 17.17%. Found: C, 58.03%; H, 7.58%; S, 17.21%.

2,15-Dithia-2,2,15,15-tetraoxo[16]paracyclophane (37)

In the manner described for the preparation of bissulfone 36, 5.04 g (15 mmol) of 2,15-dithia[16]paracyclophane (33) was oxidized with hydrogen peroxide to give 5.45 g (90.8%) of bissulfone 37 as white powder. Recrystallization of this substance from acetone afforded an analytically pure sample as colorless needles : m.p. 234-237°C; nmr (TFA) δ ppm 1.10-2.24 (unresolved broad peak, 20H, non-benzylic $-CH_2-$ at 4-13 positions),

2.84-3.30 (t, J=6Hz, 4H, $-CH_2-$ at 3 and 14 positions), 4.62 (s, 4H, $ArCH_2SO_2-$), 7.74 (s, 4H, ArH); ms (70 eV) m/e 400 (M^+). Anal. Calcd for $C_{20}H_{32}S_2O_4$: C, 59.97%; H, 8.05%; S, 16.01%. Found: C, 60.01%; H, 8.33%; S, 16.20%.

[8]Metacyclophane (42)

To a vigorously stirred mixture of 6.32 g (20 mmol) of bissulfone 34, 40 ml of carbon tetrachloride, 40 ml of cyclohexene, and 70 ml of t-butanol was added 20 g of pulverized potassium hydroxide. Upon further stirring at room-temperature for 12 h, the reaction mixture was poured into 350 ml of water and extracted with petroleum ether (50-75°C). The combined extracts were washed with water, dried over anhydrous magnesium sulfate and evaporated to give a yellow oily residue. The nmr spectrum of this material indicated the presence of both [8]metacyclophane-1,7-diene (38) and, 7,7-dichlorobicyclo [4.1.0]heptane arising from the addition of dichlorocarbene to cyclohexene. The bicyclic gem-dichloride was removed by vacuum distillation at 35°C under 0.05 mmHg, leaving relatively pure cyclophanediene 38 as indicated by the nmr spectrum of the residue.

The crude diene obtained above was dissolved in 30 ml of ethyl acetate and hydrogenated over 5% palladium on charcoal at room-temperature under 45 psi for 4 h. Removal of catalyst and evaporation of solvent gave a yellow oil which was taken up in ca 3 ml of petroleum ether (50-75°C) and chromatographed over silica gel (E. Merck 7733). The fraction eluted with

petroleum ether (50-75°C) on evaporation furnished 1.89 g (50.2%) of a colorless oil. That this substance was [8]metacyclophane[25] (42) was confirmed by nmr (CCl_4) spectrum: δ ppm 0.35-1.86 (unresolved broad peak, 12H, non-benzylic $-CH_2-$), 2.35-2.78 (t, J=5Hz, 4H, $ArCH_2-$), 6.75-7.30 (m, 4H, ArH).

Anal. Calcd for $C_{14}H_{20}$: m/e 188.1565. Found: 188.1559.

[12]Metacyclophane (43)

To a vigorously stirred mixture of 5.58 g (15 mmol) of bissulfone 35, 30 ml of carbon tetrachloride, 30 ml of cyclohexene, and 70 ml of t-butanol was added 18 g of pulverized potassium hydroxide. Upon further stirring at room-temperature for 12 h, the reaction mixture was poured into 350 ml of water and extracted with petroleum ether (50-75°C). The combined extracts were washed with water, dried over anhydrous magnesium sulfate and evaporated to give a yellow oily residue. The nmr spectrum of this material indicated the presence of both [12]metacyclophane-1,11-diene (39) and, 7,7-dichlorobicyclo[4.1.0]heptane arising from the addition of dichlorocarbene to cyclohexene. The bicyclic gem-dichloride was removed by vacuum distillation at 35°C under 0.05 mmHg, leaving relatively pure cyclophanediene 39 as indicated by the nmr spectrum of the residue.

The crude diene obtained above was dissolved in 30 ml of ethyl acetate and hydrogenated over 5% palladium on charcoal at room-temperature under 45 psi for 4 h. Removal of catalyst and evaporation of solvent gave a yellow oil which was taken up in ca 3 ml of petroleum ether (50-75°C) and chromatographed over silica gel (E. Merck 7733). The fraction eluted with

petroleum ether (50-75°C) on evaporation furnished 2.02 g (55.2%) of a colorless oil. That this substance was [12]metacyclophane (43) was confirmed by nmr (CCl_4) spectrum: δ ppm 0.50-1.82 (unresolved broad peak, 20H, non-benzylic $-CH_2-$), 2.46-2.64 (t, J=6Hz, 4H, $ArCH_2-$), 6.70-7.22 (m, 4H, ArH).

Anal. Calcd for $C_{18}H_{28}$: m/e 244.2191. Found: 244.2188.

[12]Paracyclophane (44)

To a vigorously stirred mixture of 5.58 g (15 mmol) of bissulfone 36, 30 ml of carbon tetrachloride, 30 ml of cyclohexene, and 70 ml of t-butanol was added 18 g of pulverized potassium hydroxide. Upon further stirring at room-temperature for 12 h, the reaction mixture was poured into 350 ml of water and extracted with petroleum ether (50-75°C). The combined extracts were washed with water, dried over anhydrous magnesium sulfate and evaporated to give a yellow oily residue. The nmr spectrum of this material indicated the presence of both [12]paracyclophane-1,11-diene (40) and, 7,7-dichlorobicyclo[4.1.0]heptane arising from the addition of dichlorocarbene to cyclohexene. The bicyclic gem-dichloride was removed by vacuum distillation at 35°C under 0.05 mmHg, leaving relatively pure cyclophanediene 40 as indicated by the nmr spectrum of the residue.

The crude diene obtained above was dissolved in 30 ml of ethyl acetate and hydrogenated over 5% palladium on charcoal at room-temperature under 45 psi for 4 h. Removal of catalyst and evaporation of solvent gave a yellow oil which was taken up in ca 3 ml of petroleum ether (50-75°C) and chromatographed

over silica gel (E. Merck 7733). The fraction eluted with petroleum ether (50-75°C) on evaporation furnished 1.03 g (28.1%) of a colorless oil. That this substance was [12]paracyclophane (44) was confirmed by nmr (CCl_4) spectrum: δ ppm 0.50-1.80 (unresolved broad peak, 20H, non-benzylic $-CH_2-$), 2.48-2.66 (t, J=6Hz, 4H, $ArCH_2-$), 7.00 (s, 4H, ArH); ms (70 eV) m/e 244 (M^+).
Anal. Calcd for $C_{18}H_{28}$: C, 88.45%; H, 11.55%. Found: C, 88.40%; H, 11.48%.

[14]Paracyclophane (45)

To a vigorously stirred mixture of 6.00 g (15 mmol) of bissulfone 37, 30 ml of carbon tetrachloride, 30 ml of cyclohexene, and 70 ml of t-butanol was added 18 g of pulverized potassium hydroxide. Upon further stirring at room-temperature for 12 h, the reaction mixture was poured into 350 ml of water and extracted with petroleum ether (50-75°C). The combined extracts were washed with water, dried over anhydrous magnesium sulfate and evaporated to give a yellowish residue. The nmr spectrum of this material indicated the presence of both [14]paracyclophane-1, 13-diene (41) and, 7,7-dichlorobicyclo [4.1.0]heptane arising from the addition of dichlorocarbene to cyclohexene. The bicyclic gem-dichloride was removed by vacuum distillation at 35°C under 0.05 mmHg, leaving relatively pure cyclophanediene 41 as indicated by the nmr spectrum of the residue.

The crude diene obtained above was dissolved in 30 ml of ethyl acetate and hydrogenated over 5% palladium on charcoal at room-temperature under 45 psi for 4 h. Removal of catalyst

and evaporation of solvent gave a yellow oil which was taken up in ca 3 ml of petroleum ether (50-75°C) and chromatographed over silica gel (E. Merck 7733). The fraction eluted with petroleum ether (50-75°C) on evaporation furnished 1.23 g (30.1%) of a viscous liquid, which solidified on standing. Recrystallization of this substance from ethanol afforded an analytically pure sample as colorless needles : m.p. 43-44°C; nmr (CCl_4) δ ppm 0.60-0.86 (unresolved broad peak, 24H, non-benzylic $-CH_2-$), 2.46-2.64 (t, J=6Hz, 4H, $ArCH_2-$), 7.00 (s, 4H, ArH); ms (70 eV) m/e 272 (M^+).

Anal. Calcd for $C_{20}H_{32}$: C, 88.16%; H, 11.84%. Found: C, 87.97%; H, 11.88%.

10,12-Bis(chloromethyl)[8]metacyclophane (46)

To a well stirred and drying-tube protected solution containing 0.50 g (2.66 mmol) of [8]metacyclophane (42), 3 ml of chloromethyl methyl ether, and 10 ml of carbon disulfide was added dropwise 2 ml of freshly distilled anhydrous stannic chloride over a period of approximately 10 min. Upon further stirring at room-temperature for 15 h, the reaction mixture was poured into 50 g of ice-water, and the resulting mixture was extracted repeatedly with dichloromethane. The combined extracts were washed thoroughly with water, dried over anhydrous magnesium sulfate and evaporated in vacuo to give a dark green residue which was taken up in ca 2 ml of petroleum ether (50-75°C) and chromatographed over silica gel (E. Merck 7733). The fraction eluted with petroleum ether (50-75°C) on eva-

poration afforded 559.4 mg (73.8%) of essentially pure 46 as a white solid. Recrystallization of this substance from ethanol gave analytically pure 10,12-bis(chloromethyl)[8]metacyclophane (46) as colorless needles : m.p. 68-70°C; nmr (CCl_4) δ ppm 0.70-0.92 (unresolved broad peak, 12H, non-benzylic $-CH_2-$), 2.45-3.00 (t, J=6Hz, 4H, benzylic $-CH_2-$ at 1 and 8 positions) 4.58 (s, 4H, $ArCH_2Cl$), 7.39 (2 unresolved s, 2H, ArH); ms (70 eV) m/e 284 (M^+).

Anal. Calcd for $C_{16}H_{22}Cl_2$: C, 67.37%; H, 7.77%; Cl, 24.86%. Found: C, 67.13%; H, 7.80%; Cl, 25.00%.

14,16-Bis(chloromethyl)[12]metacyclophane (47)

To a well stirred and drying-tube protected solution containing 0.50 g (2.05 mmol) of [12]metacyclophane (43), 3 ml of chloromethyl methyl ether, and 10 ml of carbon disulfide was added dropwise 2 ml of freshly distilled anhydrous stannic chloride over a period of approximately 10 min. Upon further stirring at room-temperature for 15 h, the reaction mixture was poured into 50 g of ice-water, and the resulting mixture was extracted repeatedly with dichloromethane. The combined extracts were washed thoroughly with water, dried over anhydrous magnesium sulfate and evaporated in vacuo to give a dark green residue which was taken up in ca 2 ml of petroleum ether (50-75°C) and chromatographed over silica gel (E. Merck 7733). The fraction eluted with petroleum ether (50-75°C) on evaporation afforded 529.7 mg (75.8%) of essentially pure 47 as a

white solid. Recrystallation of this product from ethanol gave analytically pure 14,16-bis(chloromethyl)[12]metacyclophane (47) as colorless prisms : m.p. 53-55°C; nmr (CCl_4) δ ppm 0.66-2.00 (unresolved broad peak, 20H, non-benzylic $-CH_2-$), 2.57-2.92 (t, J=6Hz, 4H, benzylic $-CH_2-$ at 1 and 12 positions), 4.50 (s, 4H, $ArCH_2Cl$), 6.96 (s, 1H, ArH) 7.25 (s, 1H, ArH); ms (70 eV) m/e 340 (M^+).

Anal. Calcd for $C_{20}H_{30}Cl_2$: C, 70.37%; H, 8.86%; Cl, 20.70%. Found: C, 69.99%; H, 8.99%; Cl, 20.80%.

14,17-Bis(chloromethyl)[12]paracyclophane (48)

To a well stirred and drying-tube protected solution containing 0.50 g (2.05 mmol) of [12]paracyclophane (44), 3 ml of chloromethyl methyl ether, and 10 ml of carbon disulfide was added dropwise 2 ml of freshly distilled anhydrous stannic chloride over a period of approximately 10 min. Upon further stirring at room-temperature for 15 h, the reaction mixture was poured into 50 g of ice-water, and the resulting mixture was extracted repeatedly with dichloromethane. The combined extracts were washed thoroughly with water, dried over anhydrous magnesium sulfate and evaporated *in vacuo* to give a dark green residue which was taken up in *ca* 2 ml of petroleum ether (50-75°C) and chromatographed over silica gel (E. Merck 7733). The fraction eluted with petroleum ether (50-75°C) on evaporation afforded 492.6 mg (70.5%) of essentially pure 14,17-bis(chloromethyl)[12]paracyclophane (48), as a viscous

oil: nmr (CCl_4) δ ppm 0.55-1.97 (unresolved broad peak, 20H, non-benzylic -CH_2-), 2.22-3.84 (m, 4H, benzylic -CH_2- at 1 and 12 positions), 4.40-4.85 (t, J=10Hz, 4H, ArCH_2Cl), 7.29 (s, 2H, ArH); ms (70 eV) m/e 340 (M^+).

Anal. Calcd for $C_{20}H_{30}Cl_2$: C, 70.37%; H, 8.86%; Cl, 20.70%. Found: C, 69.99%; H, 8.93%; Cl, 20.60%.

16,19-Bis(chloromethyl) [14]paracyclophane (49)

To a well stirred and drying-tube protected solution containing 0.50 g (1.84 mmol) of [14]paracyclophane (45), 3 ml of chloromethyl methyl ether, and 10 ml of carbon disulfide was added dropwise 2 ml of freshly distilled anhydrous stannic chloride over a period of approximately 10 min. Upon further stirring at room-temperature for 15 h, the reaction mixture was poured into 50 g of ice-water, and the resulting mixture was extracted repeatedly with dichloromethane. The combined extracts were washed thoroughly with water, dried over anhydrous magnesium sulfate and evaporated in vacuo to give a dark green residue which was taken up in ca 2 ml of petroleum ether (50-75°C) and chromatographed over silica gel (E. Merck 7733). The fraction eluted with petroleum ether (50-75°C) on evaporation afforded 493.1 mg (72.7%) of a viscous liquid. That this substance was 16,19-bis(chloromethyl) [14]paracyclophane (49) was confirmed by nmr (CCl_4) spectrum: δ ppm 0.55-1.92 (unresolved broad peak, 24H, non-benzylic -CH_2-), 2.22-3.24 (m, 4H, benzylic -CH_2- at 1 and 14 positions), 4.30-4.80 (t, J=10 Hz, 4H, ArCH_2Cl), 7.14 (s, 2H, ArH); ms (70 eV)

m/e 368 (M^+).

Anal. Calcd for $C_{22}H_{34}Cl_2$: C, 71.53%; H, 9.28%; Cl, 19.19%. Found: C, 71.41%; H, 9.44%; Cl, 19.00%.

Structural Proof for 10,12-Bis(chloromethyl)[8]metacyclophane (46)

(a) Dechlorination of 10,12-Bis(chloromethyl)[8]metacyclophane (46) to 10,12-Dimethyl[8]metacyclophane (50)

A magnetically stirred and drying-tube protected mixture containing 30 ml of dried tetrahydrofuran, 2.5 g (excess) of lithium aluminum hydride, and 0.50 g (1.75 mmol) of 10,12-bis(chloromethyl)[8]metacyclophane (46) was refluxed for 5 h. After destruction of unreacted lithium aluminum hydride by slow addition of ethyl acetate to the chilled reaction mixture, the resulting slurry was poured into an ice-cold solution of 0.1 M sulfuric acid. To the resulting two-layers mixture was added 30 ml of petroleum ether (50-75°C) and the organic layer was retained. The aqueous phase was further extracted with petroleum ether (50-75°C) and all the organic extracts were combined. Washing the combined organic solution with water, drying over anhydrous magnesium sulfate and solvent removal *in vacuo* gave an oily residue. This crude product was taken up in *ca* 2 ml of petroleum ether (50-75°C) and chromatographed over silica gel (E. Merck 7733). The fraction eluted from petroleum ether (50-75°C) on evaporation yielded a viscous liquid, which solidified on cooling. Recrystallization of this substance from ethanol afforded 0.23 g (60.7%) of

10,12-dimethyl[8]metacyclophane (50) as colorless needles: m.p. 41-42°C; nmr (CCl_4) δ ppm 0.55-1.97 (unresolved broad peak , 12H, non-benzylic $-CH_2-$), 2.22 (s, 6H, $ArCH_3$), 2.48-2.80 (t, J=6Hz, 4H, $ArCH_2-$), 6.96 (s, 1H, ArH), 7.15 (s, 1H, ArH); ms (70 eV) m/e 216 (M^+).

Anal. Calcd for $C_{16}H_{24}$: C, 88.82%; H, 11.18%. Found: C, 88.52%; H, 11.48%.

(b) Independent Preparation of 10,12-Dimethyl[8]metacyclophane (50)

(i) 4,6-Bis(mercaptomethyl)-m-xylene (52)

A mixture of 10.15 g (500 mmol) of 4,6-bis(chloromethyl)-m-xylene which was obtained by the bischloromethylation of m-xylene[10], 10 g (excess) of thiourea, and 250 ml of ethanol was refluxed with vigorous stirring for 2 h. Upon cooling, the resulting adduct was collected by suction filtration. This substance was heated in 200 ml of 10% aqueous potassium hydroxide for about 1.5 h. The alkaline solution was chilled in an ice-bath and acidified with concentrated hydrochloric acid. Extraction with dichloromethane followed by recrystallization (petroleum ether 50-75°C) of the crude organic residue gave 8.50 g (85.8%) of 4,6-bis(mercaptomethyl)-m-xylene (52) as colorless leaflets, m.p. 48-50°C.

(ii) 2,9-Dithia-12,14-dimethyl[10]metacyclophane (53)

To a vigorously stirred solution of 7.5 g of potassium hydroxide in 1.2 l of 95% ethanol at room-temperature was added dropwise a solution of 7.32 g (30 mmol) of

1,6-dibromohexane and 5.94 g (30 mmol) of 4,6-bis(mercaptomethyl)-m-xylene (52) in 500 ml of benzene over a period of 30 h. Upon further stirring for 12 h, the solvent was evaporated in vacuo. To the residue was added 500 ml of water, and the resulting aqueous suspension was repeatedly extracted with dichloromethane. The combined extracts were washed successively with brine and water, dried over anhydrous magnesium sulfate and evaporated to give a yellow liquid which was taken up in ca 8 ml of benzene and chromatographed over silica gel (E. Merck 7733). The fraction eluted with petroleum ether (50-75°C) - benzene (3:1) on evaporation afforded 6.05 g (72.0%) of a white solid. Recrystallization of this substance from n-hexane gave analytically pure 2,9-dithia-12,14-dimethyl [10]metacyclophane (53) as colorless needles: m.p. 97-98°C; nmr (CCl_4) δ ppm 1.00-1.51 (unresolved broad peak, 8H, non-benzylic $-CH_2-$), 2.10-2.62 (overlapped peaks, 10H, $ArCH_3$ and non-benzylic $-CH_2-$ at 3 and 8 positions), 3.64 (s, 4H, benzylic $-CH_2-$), 6.95-7.13 (2 overlapped s, 2H, ArH); ms (70 eV) m/e 280 (M^+). Anal. Calcd for $C_{16}H_{24}S_2$: C, 68.52%; H, 8.62%; S, 22.86%. Found: C, 68.59%; H, 8.82%; S, 23.00%.

(iii) 2,9-Dithia-2,2,9,9-tetraoxo-12,14-dimethyl [10]-metacyclophane (55)

A mixture of 4.20 g (15 mmol) of dithiacyclophane 53, 40 ml of glacial acetic acid, and 18 ml of 30% aqueous hydrogen peroxide was heated with stirring at 100°C for 4 h. On

refrigeration overnight, the precipitate formed was filtered off, washed successively with 5% sodium hydroxide and water, and dried at 80°C to afford 4.97 g (96.3%) of bissulfone 55 as white powder. Recrystallization of this substance from acetone afforded an analytically pure sample as needles : m.p. >300°C; nmr (TFA) δ ppm 1.25-1.93 (unresolved broad peak, 8H, non-benzylic $-CH_2-$ at 4-7 positions), 2.50 (s, 6H, $ArCH_3$), 2.80-3.31 (t, 4H, non-benzylic $-CH_2-$ at 3 and 8 positions), 4.52 (s, 4H, $ArCH_2SO_2-$), 7.40 (s, 1H, ArH), 7.58 (s, 1H, ArH); ms (70 eV) m/e 344 (M^+).

Anal. Calcd for $C_{16}H_{24}S_2O_4$: C, 55.79%; H, 7.02%; S, 18.61%. Found: C, 55.73%; H, 7.14%; S, 18.70%.

(iv) 10,12-Dimethyl[8]metacyclophane (50)

To a vigorously stirred mixture of 3.44 g (10 mmol) of bissulfone 55, 40 ml of carbon tetrachloride, 30 ml of cyclohexene and 60 ml of t-butanol was added 20 g of pulverized potassium hydroxide. Upon further stirring at room-temperature for 12 h, the reaction mixture was poured into 400 ml of water and extracted with petroleum ether (50-75°C). The combined extracts were washed with water, dried over anhydrous magnesium sulfate and evaporated to give a yellow oily residue. The crude product was then distilled at 35°C under 0.05 mmHg to remove all 7,7-dichlorobicyclo[4.1.0]heptane which was formed in the course of reaction. That the remaining residue contained

chiefly 10,12-dimethyl [8]metacyclophane-1,7-diene (57) was indicated by the presence of both aromatic and olefinic protons in the nmr spectrum.

The crude diene obtained above was dissolved in 30 ml of ethyl acetate and hydrogenated over 5% palladium on charcoal at room temperature under 45 psi for 3 h. Removal of catalyst and evaporation of solvent gave a yellow oil which was taken up in ca 2 ml of petroleum ether (50-75°C) and chromatographed over silica gel (E. Merck 7733). The fraction eluted with petroleum ether (50-75°C) on evaporation furnished 1.1 g (50.9%) of a viscous oil which solidified on standing. Recrystallization of this compound with ethanol gave cyclophane 50 as colorless needles: m.p. 41-42°C, undepressed admixed with the sample obtained from (a).

The two samples of 50 obtained from the two independent routes described above showed completely identical nmr and ir spectra.

Structural Proof for 14,16-Bis(chloromethyl) [12]metacyclophane (47)

(a) Dechlorination of 14,16-Bis(chloromethyl) [12]metacyclophane (47) to 14,16-Dimethyl [12]metacyclophane (51)

A magnetically stirred and drying-tube protected mixture containing 30 ml of dried tetrahydrofuran, 2.5 g (excess) of lithium aluminum hydride, and 0.51 g (1.50 mmol) of 14,16-bis(chloromethyl) [12]metacyclophane (47) was refluxed for 5 h. After destruction of unreacted lithium aluminum hydride by slow addition of ethyl acetate to the chilled reaction mixture,

the resulting slurry was poured into an ice-cold solution of 0.1 M sulfuric acid. To the resulting two-layers mixture was added 30 ml of petroleum ether (50-75°C) and the organic layer was retained. The aqueous phase was further extracted with petroleum ether (50-75°C) and all the organic extracts were combined. Washing the combined organic solution with water, drying over anhydrous magnesium sulfate and solvent removal *in vacuo* gave a yellow oil. This crude product was taken up in *ca* 2 ml of petroleum ether (50-75°C) and chromatographed over silica gel (E. Merck 7733). The fraction eluted with petroleum ether (50-75°C) on evaporation yielded 0.21 g (51.5%) of pure 14,16-dimethyl [12]metacyclophane (51) as a viscous liquid: nmr (CCl_4) δ ppm 0.92-1.85 (unresolved broad peak, 20H, non-benzylic $-CH_2-$), 2.20 (s, 6H, $ArCH_3$), 2.40-2.72 (t, J=6Hz, 4H, benzylic $-CH_2-$ at 1 and 12 positions), 6.78-6.95 (unresolved s, 2H, ArH); ms (70 eV) m/e 272 (M^+). *Anal*. Calcd for $C_{20}H_{32}$: C, 88.16%; H, 11.84%. Found: C, 88.11%; H, 11.59%.

(b) Independent Preparation of 14,16-Dimethyl [12]metacyclophane (51)

(i) 2,13-Dithia-16,18-dimethyl [14]metacyclophane (54)

To a vigorously stirred solution of 7.5 g of potassium hydroxide in 1.2 l of 95% ethanol at room-temperature was added dropwise a solution of 9.00 g (30 mmol) of 1,10-dibromodecane and 5.94 g (30 mmol) of 4,6-bis(mercaptomethyl)-*m*-xylene (52) in 500 ml of benzene over a peroid

of 30 h. Upon further stirring for 12 h, the solvent was evaporated *in vacuo*. To the residue was added 500 ml of water, and the resulting aqueous suspension was repeatedly extracted with dichloromethane. The combined extracts were washed successively with brine and water, dried over anhydrous magnesium sulfate and evaporated to give a yellow liquid which was taken up in *ca* 8 ml of benzene and chromatographed over silica gel (E. Merck 7733). The fraction eluted with petroleum ether (50-75°C) - benzene (3:1) on evaporation afforded 6.58 g (65.3%) of a white solid. Recrystallization of this substance from ethanol gave analytically pure 2,13-dithia-16,18-dimethyl [14]metacyclophane (54) as colorless plates: m.p. 65-66°C; nmr (CCl_4) δ ppm 1.20-1.92 (unresolved broad peak, 16H, non-benzylic $-CH_2-$ at 4-11 positions), 2.20-2.61 (overlapped peaks, 10H, $ArCH_3$ and non-benzylic $-CH_2-$ at 3 and 12 positions), 3.60 (s, 4H, benzylic $-CH_2-$ at 1 and 14 positions), 6.88-7.07 (2 overlapped s, 2H, ArH); ms (70 eV) m/e 336 (M^+).

Anal. Calcd for $C_{20}H_{32}S_2$: C, 71.37%; H, 9.58%; S, 19.05%. Found: C, 71.00%; H, 9.51%; S, 19.00%.

(ii) *2,13-Dithia-2,2,13,13-tetraoxo-16,18-dimethyl* [14]-*metacyclophane* (56)

A mixture of 5.04 g (15 mmol) of dithiacyclophane 54, 40 ml of glacial acetic acid, and 18 ml of 30% aqueous hydrogen peroxide was heated with stirring at 100°C for 4 h. On

refrigeration overnight, the precipitate formed was filtered off, washed successively with 5% sodium hydroxide and water, and dried at 80°C to afford 5.35 g (89.2%) of bissulfone 56 as white powder. Recrystallization of this substance from acetone afforded an analytically pure sample as needles: m.p. 219-220°C; nmr (TFA) δ ppm 1.10-2.18 (unresolved broad peak, 16H, non-benzylic $-CH_2-$ at 4-11 positions), 2.51 (s, 6H, $ArCH_3$), 3.08-3.45 (t, J=6Hz, 4H, non-benzylic $-CH_2-$ at 3 and 12 positions), 4.61 (s, 4H, benzylic $-CH_2-$ at 1 and 14 positions), 7.36-7.65 (2 overlapped s, 2H, ArH); ms (70 eV) m/e 400 (M^+).

Anal. Calcd for $C_{20}H_{32}S_2O_4$: C, 59.97%; H, 8.05%; S, 16.01%. Found: C, 59.74%; H, 8.03%; S, 16.00%.

(iii) 14,16-Dimethyl [12]metacyclophane (51)

To a vigorously stirred mixture of 4.00 g (10 mmol) of bissulfone 56, 40 ml of carbon tetrachloride, 30 ml of cyclohexene and 60 ml of t-butanol was added 20 g of pulverized potassium hydroxide. Upon further stirring at room-temperature for 12 h, the reaction mixture was poured into 400 ml of water and extracted with petroleum ether (50-75°C). The combined extracts were washed with water, dried over anhydrous magnesium sulfate and evaporated to give a yellow oily residue. The crude product was then distilled at 35°C under 0.05 mmHg to remove all 7,7-dichlorobicyclo [4.1.0] heptane which was formed in the course of reaction. That the remaining residue contained

chiefly 14,16-dimethyl [12]metacyclophane-1,11-diene (58) was indicated by the presence of both aromatic and olefinic protons in the nmr spectrum.

The crude diene obtained above was dissolved in 30 ml of ethyl acetate and hydrogenated over 5% palladium on charcoal at room-temperature under 45 psi for 3 h. Removal of catalyst and evaporation of solvent gave a yellow oil which was taken up in ca 2 ml of petroleum ether (50-75°C) and chromatographed over silica gel (E. Merck 7733). The fraction eluted with petroleum ether (50-75°C) on evaporation furnished 1.50 g (55.1%) of pure 14,16-dimethyl [12]metacyclophane (51) as a colorless oil.

The two samples of 51 obtained from the two independent routes described above showed completely identical nmr spectrum.

Structural Proof for 14,17-Bis(chloromethyl) [12]paracyclophane (48)

(a) Dechlorination of 14,17-Bis(chloromethyl) [12]paracyclophane (48) to 14,17-Dimethyl [12]paracyclophane (59)

A magnetically stirred and drying-tube protected mixture containing 30 ml of dried tetrahydrofuran, 2.5 g (excess) of lithium aluminum hydride, and 0.51 g (1.50 mmol) of 14,17-bis(chloromethyl) [12]paracyclophane (48) was refluxed for 5 h. After destruction of unreacted lithium aluminum hydride by slow addition of ethyl acetate to the chilled reaction mixture, the resulting slurry was poured into an ice-cold solution of 0.1 M sulfuric acid. To the resulting two-layers mixture was added 30 ml of petroleum ether (50-75°C) and the organic layer was retained. The aqueous phase was further extracted with

petroleum ether (50-75°C) and all the organic extracts were combined. Washing the combined organic solution with water, drying over anhydrous magnesium sulfate and solvent removal *in vacuo* gave a yellow oil. This crude product was taken up in *ca* 2 ml of petroleum ether (50-75°C) and chromatographed over silica gel (E. Merck 7733). The fraction eluted from petroleum ether (50-75°C) on evaporation yielded 0.23 g (56.4%) of pure 14,17-dimethyl [12]paracyclophane (59) as a viscous liquid: nmr (CCl_4) δ ppm 0.58-1.99 (unresolved broad peak, 20H, non-benzylic $-CH_2-$), 2.10-3.12 (overlapped sharp peaks, 10H, $ArCH_3$ and benzylic $-CH_2-$ at 1 and 12 positions), 6.91 (s, 2H, ArH).

Anal. Calcd for $C_{20}H_{32}$: m/e 272.2504. Found: 272.2513.

(b) Independent Preparation of 14,17-Dimethyl [12]paracyclophane (59)

(i) 2,5-Bis(mercaptomethyl)-p-xylene (61)

A mixture of 10.15 g (500 mmol) of 2,5-bis(chloromethyl)-p-xylene which was obtained by the bischloromethylation of p-xylene[10], 10 g (excess) of thiourea, and 250 ml of ethanol was refluxed with vigorous stirring for 2 h. Upon cooling, the resulting adduct was collected by suction filtration. This substance was heated in 200 ml of 10% aqueous potassium hydroxide for about 1.5 h. The alkaline solution was chilled in an ice-bath and acidified with concentrated hydrochloric acid. Extraction with dichloromethane followed by recrystallization (n-hexane) of the crude organic residue gave 8.70 g (87.9%) of 2,5-bis(mercaptomethyl)-p-xylene (61) as colorless needles, m.p. 76-78°C.

(ii) 2,13-Dithia-16,19-dimethyl [14]paracyclophane (62)

To a vigorously stirred solution of 7.5 g potassium hydroxide in 1.2 l of 95% ethanol at room-temperature was added dropwise a solution of 9.00 g (30 mmol) of 1,10-dibromodecane and 5.94 g (30 mmol) of 2,5-bis(mercaptomethyl)-p-xylene (61) in 500 ml of benzene over a period of 30 h. Upon further stirring for 12 h, the solvent was evaporated *in vacuo*. To the residue was added 500 ml of water, and the resulting aqueous suspension was repeatedly extracted with dichloromethane. The combined extracts were washed successively with brine and water, dried over anhydrous magnesium sulfate and evaporated to give a yellow liquid which was taken up in *ca* 8 ml of benzene and chromatographed over silica gel (E. Merck 7733). The fraction eluted with petroleum ether (50-75°C) - benzene (3:1) on evaporation afforded 6.64 g (65.9%) of a white solid. Recrystallization of this substance from ethanol gave analytically pure 2,13-dithia-16,19-dimethyl [14]paracyclophane (62) as colorless needles: m.p. 47-49°C; nmr (CCl_4) δ ppm 0.79-1.18 (unresolved broad peak, 16H, non-benzylic $-CH_2-$ at 4-11 positions), 2.10-2.48 (overlapped sharp peaks, 10H, $ArCH_3$ and non-benzylic $-CH_2-$ at 3 and 12 positions), 3.30-3.80 (q, 4H, benzylic $-CH_2-$ at 1 and 14 positions), 7.05 (s, 2H, ArH); ms (70 eV) m/e 336 (M^+).

Anal. Calcd for $C_{20}H_{32}S_2$: C, 71.37%; H, 9.58%; S, 19.05%. Found: C, 71.05%; H, 9.58%; S, 19.10%.

(iii) 2,13-Dithia-2,2,13,13-tetraoxo-16,19-dimethyl [14] paracyclophane (64)

A mixture of 5.04 g (15 mmol) of dithiacyclophane 62, 40 ml of glacial acetic acid, and 18 ml of 30% aqueous hydrogen peroxide was heated with stirring at 100°C for 4 h. On refrigeration overnight, the precipitate formed was filtered off, washed successively with 5% sodium hydroxide and water, and dried at 80°C to afford 5.60 g (93.3%) of bissulfone 64 as white powder. Recrystallization of this substance from acetone afforded an analytically pure sample as prisms: m.p. 185-187°C; nmr (TFA) δ ppm 0.82-2.15 (unresolved broad peak, 16H, non-benzylic $-CH_2-$ at 4-11 positions), 2.35-3.00 (overlapped sharp peaks, 10H, $ArCH_3$ and non-benzylic $-CH_2-$ at 3 and 12 positions), 4.02-4.78 (q, 4H, benzylic $-CH_2-$ at 1 and 14 positions), 7.54 (s, 2H, ArH); ms (70 eV) m/e 400 (M^+).

Anal. Calcd for $C_{20}H_{32}S_2O_4$: C, 59.97%; H, 8.05%; S, 16.01%. Found: C, 60.06%; H, 8.14%; S, 16.40%.

(iv) 14,17-Dimethyl [12] paracyclophane (59)

To a vigorously stirred mixture of 4.00 g (10 mmol) of bissulfone 64, 40 ml of carbon tetrachloride, 30 ml of cyclohexene and 60 ml of t-butanol was added 20 g of pulverized potassium hydroxide. Upon further stirring at room temperature for 12 h, the reaction mixture was poured into 400 ml of water and extracted with petroleum ether (50-75°C). The combined extracts were washed with water, dried over anhydrous magnesium sulfate and evaporated to give a yellow oily residue. The crude product was then distilled at 35°C under 0.05 mmHg to remove all 7,7-

dichlorobicyclo[4.1.0]heptane which was formed in the course of reaction. That the remaining residue contained chiefly 14,17-dimethyl [12]paracyclophane-1,11-diene (66) was indicated by the presence of both aromatic and olefinic protons in the nmr spectrum.

The crude diene obtained above was dissolved in 30 ml of ethyl acetate and hydrogenated over 5% palladium on charcoal at room-temperature under 45 psi for 3 h. Removal of catalyst and evaporation of solvent gave a yellow oil which was taken up in ca 2 ml of petroleum ether (50-75°C) and chromatographed over silica gel (E. Merck 7733). The fraction eluted with petroleum ether (50-75°C) on evaporation furnished 0.85 g (31.3%) of pure 14,17-dimethyl [12]paracyclophane (59) as a viscous oil.

The two samples of 59 obtained from two independent routes described above showed completely identical nmr spectrum.

Structural Proof for 16,19-Bis(chloromethyl)[14]paracyclophane (49)

(a) Dechlorination of 16,19-Bis(chloromethyl)[14]paracyclophane (49) to 16,19-Dimethyl [14]paracyclophane (60)

A magnetically stirred and drying-tube protected mixture containing 30 ml of dried tetrahydrofuran, 2.5 g (excess) of lithium aluminum hydride, and 0.55 g (1.50 mmol) of 16,19-bis(chloromethyl)[14]paracyclophane (49) was refluxed for 5 h. After destruction of unreacted lithium aluminum hydride by slow addition of ethyl acetate to the chilled reaction mixture, the resulting slurry was poured into an ice-cold solution of 0.1 M sulfuric acid. To the resulting two-layers mixture was

added 30 ml of petroleum ether (50-75°C) and the organic layer was retained. The aqueous phase was further extracted with petroleum ether (50-75°C) and all the organic extracts were combined. Washing the combined organic solution with water, drying over anhydrous magnesium sulfate and solvent removal *in vacuo* gave a yellow oil. This crude product was taken up in *ca* 2 ml of petroleum ether (50-75°C) and chromatographed over silica gel (E. Merck 7733). The fraction eluted from petroleum ether (50-75°C) on evaporation yielded 0.28 g (62.6%) of pure 16,19-dimethyl[14]paracyclophane (60) as an oily liquid: nmr (CCl_4) δ ppm 0.61-1.95 (unresolved broad peak, 24H, non-benzylic $-CH_2-$), 2.10-3.12 (overlapped peaks, 10H, $ArCH_3$ and benzylic $-CH_2-$), 6.89 (s, 2H, ArH).
Anal. Calcd for $C_{22}H_{36}$: m/e 300.2817. Found: 300.2823.

(b) *Independent Preparation of 16,19-Dimethyl[14]paracyclophane (60)*

(i) *2,15-Dithia-18,21-dimethyl[16]paracyclophane (63)*

To a vigorously stirred solution of 7.5 g potassium hydroxide in 1.2 l of 95% ethanol at room-temperature was added dropwise a solution of 9.84 g (30 mmol) of 1,12-dibromododecane and 5.94 g (30 mmol) of 2,5-bis(mercaptomethyl)-*p*-xylene (61) in 500 ml of benzene over a period of 30 h. Upon further stirring for 12 h, the solvent was evaporated *in vacuo*. To the residue was added 500 ml of water, and the resulting aqueous suspension was repeatedly extracted with dichloromethane. The combined extracts were

washed successively with brine and water, dried over anhydrous magnesium sulfate and evaporated to give a yellow liquid which was taken up in ca 8 ml of benzene and chromatographed over silica gel (E. Merck 7733). The fraction eluted with petroleum ether (50-75°C) - benzene (3:1) on evaporation afforded 7.23 g (66.2%) of essentially pure 2,15-dithia-18,21-dimethyl [16] paracyclophane (63), as a white solid: m.p. 48-50°C; nmr (CCl_4) δ ppm 1.05-1.95 (unresolved broad peak, 20H, non-benzylic $-CH_2-$ at 4-13 positions), 2.15-2.55 (overlapped peaks, 10H, $ArCH_3$ and non-benzylic $-CH_2-$ at 3 and 14 positions), 3.65 (s, 4H, $ArCH_2S-$), 7.06 (s, 2H, ArH).

Anal. Calcd for $C_{22}H_{36}S_2$: m/e 364.2258. Found: 364.2270.

(ii) 2,15-Dithia-2,2,15,15-tetraoxo-18,21-dimethyl [16]-paracyclophane (65)

A mixture of 5.46 g (15 mmol) of dithiacyclophane 63, 40 ml of glacial acetic acid, and 18 ml of 30% aqueous hydrogen peroxide was heated with stirring at 100°C for 4 h. On refrigeration overnight, the precipitate formed was filtered off, washed successively with 5% sodium hydroxide and water, and dried at 80°C to afford 5.70 g (88.8%) of bissulfone 65 as white powder. Recrystallization of this substance from acetone afforded an analytically pure sample as prisms: m.p. 186-188°C; nmr (TFA) δ ppm 1.05-2.22 (unresolved broad peak, 20H, non-benzylic $-CH_2-$ at 4-13 positions), 2.54 (s, 6H, $ArCH_3$), 2.60-2.95 (t, J=6Hz, 4H, non-benzylic $-CH_2-$ at 3 and 14 positions), 4.70 (s, 4H, $ArCH_2SO_2-$), 7.65 (s, 2H, ArH);

ms (70 eV) m/e 428 (M^+).

Anal. Calcd for $C_{22}H_{36}S_2O_4$: C, 61,65%; H, 8.46%; S, 14.96%. Found:: C, 61.88%; H, 8.77%; S, 14.90%.

(iii) 16,19-Dimethyl [14] paracyclophane (60)

To a vigorously stirred mixture of 4.28 g (10 mmol) of bissulfone 65, 40 ml of carbon tetrachloride, 30 ml of cyclohexene and 60 ml of t-butanol was added 20 g of pulverized potassium hydroxide. Upon further stirring at room-temperature for 12 h, the reaction mixture was poured into 400 ml of water and extracted with petroleum ether (50-75°C). The combined extracts were washed with water, dried over anhydrous magnesium sulfate and evaporated to give a yellow oily residue. The crude product was then distilled at 35°C under 0.05 mmHg to remove all 7,7-dichlorobicyclo [4.1.0] heptane which was formed in the course of reaction. That the remaining residue contained chiefly 16,19-dimethyl [14] paracyclophane-1,13-diene (67) was indicated by the presence of both aromatic and olefinic protons in the nmr spectrum.

The crude diene obtained above was dissolved in 30 ml of ethyl acetate and hydrogenated over 5% palladium on charcoal at room temperature under 45 psi for 3 h. Removal of catalyst and evaporation of solvent gave a yellow oil which was taken up in ca 2 ml of petroleum ether (50-75°C) and chromatographed over silica gel (E. Merck 7733). The fraction eluted with petroleum ether

(50-75°C) on evaporation furnished 0.70 g (23.3%) of pure 16,19-dimethyl [14]paracyclophane (60) as a viscous oil.

The two samples of 60 obtained from two independent routes described above showed completely identical nmr spectrum.

2',13'-Dithia [8] [14] metacyclophane (68)

To a well stirred solution of 3.0 g of potassium hydroxide in 300 ml of 95% ethanol at room-temperature was added dropwise a solution of 313.5 mg (1.1 mmol) of 10,12-bis(chloromethyl)-[8] metacyclophane (46) and 226.6 mg (1.1 mmol) of 1,10-decanedithiol in 250 ml of benzene over a period of 24 h. Upon further stirring for 20 h, the solvent was evaporated in vacuo. To the residue was added 150 ml of water, and the resulting aqueous suspension was repeatedly extracted with petroleum ether (50-75°C). The combined extracts were washed successively with brine and water, dried over anhydrous magnesium sulfate and evaporated to give a solid residue. The crude product was taken up in ca 2 ml of benzene and chromatographed over silica gel (E. Merck 7733). The fraction eluted with petroleum ether (50-75°C) - benzene (3:1) on evaporation gave 346.7 mg (75.4%) of essentially pure 2',13'-dithia [8] [14] metacyclophane (68). Recrystallization of this compound from acetone furnished an analytically pure sample as colorless needles: m.p. 85-86°C; nmr (CCl_4) δ ppm 0.66-1.82 (unresolved broad peak, 28H, non-benzylic $-CH_2-$ at 2-7 and 4'-11' positions), 2.22-2.94

(2 overlapped t, 8H, $-CH_2-$ at 1,8 and 3',12' positions), 3.60 (s, 4H, $ArCH_2S-$), 7.05 (s, 1H, ArH), 7.27 (s, 1H, ArH); ms (70 eV) m/e 418 (M^+).

Anal. Calcd for $C_{26}H_{42}S_2$: C, 74.58%; H, 10.11%; S, 15.31%. Found: C, 74.31%; H, 10.08%; S, 14.90%.

2',13'-Dithia [12] [14]metacyclophane (69)

In the manner described for the preparation of dithiacyclophane 68, 375.1 mg (1.10 mmol) of 14,16-bis(chloromethyl)-[12]metacyclophane (47) and 226.6 mg (1.10 mmol) of 1,10-decanedithiol were cyclocoupled in the presence of potassium hydroxide to give 366.5 mg (70.3%) of essentially pure 2',13'-dithia-[12] [14]metacyclophane (69). Recrystallization of this compound from acetone yielded an analytically pure sample as colorless prisms: m.p. 106-108°C; nmr (CCl_4) δ ppm 1.05-1.94 (unresolved broad peak, 36H, non-benzylic $-CH_2-$ at 2-11 and 4'-11' positions), 2.20-2.92 (2 overlapped t, 8H, $-CH_2-$ at 1,12 and 3',12' positions), 3.60 (s, 4H, $ArCH_2S-$), 6.92-7.08 (2 partially overlapped s, 2H, ArH); ms (70 eV) m/e 474 (M^+).

Anal. Calcd for $C_{30}H_{50}S_2$: C, 75.88%; H, 10.61%; S, 13.50%. Found: C, 75.63%; H, 10.69%; S, 13.30%.

2',13'-Dithia [12] [14]paracyclophane (70)

To a well stirred solution of 3.0 g of potassium hydroxide in 300 ml of 95% ethanol at room-temperature was added dropwise a solution of 375.1 mg (1.10 mmol) of 14,17-bis(chloromethyl)-

[12]paracyclophane (48) and 226.6 mg (1.10 mmol) of 1,10-decanedithiol in 250 ml of benzene over a period of 24 h. Upon further stirring for 20 h, the solvent was evaporated in vacuo. To the residue was added 150 ml of water, and the resulting aqueous suspension was repeatedly extracted with petroleum ether (50-75°C). The combined extracts were washed successively with brine and water, dried over anhydrous magnesium sulfate and evaporated to give a solid residue. The crude product was taken up in ca 2 ml of benzene and chromatographed over silica gel (E. Merck 7733). The fraction eluted with petroleum ether (50-75°) - benzene (4:1) on evaporation gave 363.9 mg (69.8%) of essentially pure 2',13'-dithia[12][14]paracyclophane (70). Recrystallization of this compound from acetone furnished an analytically pure sample as colorless needles: m.p. 50-52°C; nmr (CCl_4) δ ppm 0.50-2.00 (unresolved broad peak, 36H, non-benzylic $-CH_2-$ at 2-11 and 4'-11' positions), 2.01-3.28 (overlapped peaks, 8H, $-CH_2-$ at 1,12 and 3',12' positions), 3.30-4.18 (q, J=12Hz, 4H, $ArCH_2S-$), 7.16 (s, 2H, ArH); ms (70 eV) m/e 474 (M^+).

Anal. Calcd for $C_{30}H_{50}S_2$: C, 75.88%; H, 10.61%; S, 13.50%. Found: C, 75.49%; H, 10.83%; S. 13.60%.

2,13-Dithia[14][14]paracyclophane (71)

In the manner described for the preparation of dithiacyclophane 70, 405.9 mg (1.10 mmol) of 16,19-bis(chloromethyl)-[14]paracyclophane (49) and 226.6 mg (1.10 mmol) of 1,10-decane-

dithiol were cyclocoupled in the presence of potassium hydroxide to give 406.4 mg (73.6%) of essentially pure 2,13-dithia-[14][14]paracyclophane (71). Recrystallization of this compound from acetone yielded an analytically pure sample as colorless needles: m.p. 128-130°C; nmr (CCl_4) δ ppm 0.62-1.98 (unresolved broad peak, 40H, $-CH_2-$ at 2-13 positions of the tetradecamethylene bridge and at 4-11 positions of the dithia bridge), 2.00-3.25 (overlapped peaks, 8H, $-CH_2-$ at 1,14 positions of the tetradecamethylene bridge and at 3,12 positions of the dithia bridge), 3.32-4.20 (q, J=12Hz, 4H, $ArCH_2S-$), 7.18 (s, 2H, ArH); ms (70 eV) m/e 502 (M^+).

Anal. Calcd for $C_{32}H_{54}S_2$: C, 76.43%; H, 10.82%; S, 12.75%. Found: C, 76.77%; H, 10.56%; S, 12.60%.

2',13'-Dithia-2',2',13',13'-tetraoxo[8][14]metacyclophane (72)

To a stirred solution of 418.0 mg (1.00 mmol) of 2',13'-dithia[8][14]metacyclophane (68) in 15 ml of chloroform at room-temperature was added dropwise a solution of 2.5 g (excess) of 90% m-chloroperbenzoic acid in 30 ml of chloroform over a period of 1 h. After further stirring for 12 h, the mixture was diluted with chloroform (ca 50 ml) until a clear solution was obtained. The organic solution was washed successively with 5% aqueous potassium hydroxide and water, dried over anhydrous magnesium sulfate and evaporated in vacuo to give 462.7 mg (96.0%) of 2',13'-dithia-2',2',13',13'-tetraoxo[8][14]metacyclophane (72). Recrystallization of this substance from acetone furnished an analytically pure sample as colorless needles: m.p. 256-258°C; nmr ($CDCl_3$)

δ ppm 0.62-2.18 (unresolved broad peak, 28H, non-benzylic $-CH_2-$ at 2-7 and 4'-11' positions), 2.71-3.12 (2 overlapped t, 8H, $-CH_2-$ at 1,8 and 3',12' positions), 4.33 (s, 4H, $ArCH_2SO_2-$) 7.50 (s, 1H, ArH), 7.61 (s, 1H, ArH); ms (70 eV) m/e 482 (M^+).

Anal. Calcd for $C_{26}H_{42}S_2O_4$: C, 64,69%; H, 8.77%; S, 13.28%. Found: C, 64.31%; H, 8.72%.

2',13'-Dithia-2',2',13',13'-tetraoxo [12][14]metacyclophane (73)

In the manner described for the preparation of bissulfone 72, 474.0 mg (1.00 mmol) of 2',13'-dithia [12][14]metacyclophane (69) was oxidized with m-chloroperbenzoic acid to give 483.0 mg (89.8%) of essentially pure 2',13'-dithia-2',2',13',13',-tetraoxo-[12][14]metacyclophane (73) as a white solid. Recrystallization of this compound from acetone yielded an analytically pure sample as colorless prisms: m.p. 274-276°C; nmr (TFA) δ ppm 0.80-2.25 (unresolved broad peak, 36H, non-benzylic $-CH_2-$ at 2-11 and 4'-11' positions), 2.75-3.50 (2 unresolved t, 8H, $-CH_2-$ at 1,12 and 3',12' positions), 4.55 (s, 4H, $ArCH_2SO_2-$), 7.45 (s, 1H, ArH), 7.65 (s, 1H, ArH); ms (70 eV) m/e 538 (M^+).

Anal. Calcd for $C_{30}H_{50}S_2O_4$: C, 66.87%; H, 9.35%; S, 11.90%. Found: C, 66.92%; H, 9.24%; S, 11.80%.

2',13'-Dithia-2',2',13',13'-tetraoxo [12] [14]paracyclophane (74)

To a stirred solution of 474.0 mg (1.00 mmol) of 2',13'-dithia [12][14]paracyclophane (70) in 15 ml of chloroform at room-temperature was added dropwise a solution of 2.5 g

(excess) of 90% m-chloroperbenzoic acid in 30 ml of chloroform over a period of 1 h. After further stirring for 12 h, the mixture was diluted with chloroform (ca 50 ml) until a clear solution was obtained. The organic solution was washed successively with 5% aqueous potassium hydroxide and water, dried over anhydrous magnesium sulfate and evaporated in vacuo to give 493.5 mg (91.7%) of essentially pure 2',13'-dithia-2',2',13',13'-tetraoxo [12] [14]paracyclophane (74). Recrystallization of this substance from acetone furnished an analytically pure sample as colorless needles: m.p. 248-250°C; nmr ($CDCl_3$) δ ppm 0.50-2.15 (unresolved broad peak, 36H, non-benzylic $-CH_2-$ at 2-11 and 4'-11' positions), 2.35-3.30 (overlapped peaks, 8H, $-CH_2-$ at 1,12 and 3',12' positions), 3.98-4.85 (q, J=12Hz, 4H, $ArCH_2SO_2-$), 7.50 (s, 2H, ArH); ms (70 eV) m/e 538 (M^+).

Anal. Calcd for $C_{30}H_{50}S_2O_4$: C, 66.87%; H, 9.35%; S, 11.90%. Found: C, 66.56%; H, 9.22%; S, 12.10%.

2,13-Dithia-2,2,13,13-tetraoxo [14] [14] paracyclophane (75)

In the manner described for the preparation of bissulfone 74, 502.0 mg (1.00 mmol) of 2,13-dithia [14] [14] paracyclophane (71) was oxidized with m-chloroperbenzoic acid to give 538.8 mg (95.2%) of essentially pure 2,13-dithia-2,2,13,13-tetraoxo-[14] [14]paracyclophane (75) as a white solid. Recrystallization of this compound from acetone yielded an analytical pure sample as colorless prisms: m.p. 158-160°C; nmr ($CDCl_3$) δ ppm 0.55-2.06 (unresolved broad peak, 40H, $-CH_2-$ at 2-13 positions

of the tetradecamethylene bridge and at 4-11 positions of the dithia bridge), 2.38-3.25 (overlapped peaks, 8H, $-CH_2-$ at 1,14 positions of the tetradecamethylene bridge and at 3,12 positions of the dithia bridge), 3.95-4.82 (q, J=12Hz, 4H, $ArCH_2SO_2-$), 7.56 (s, 2H, ArH); ms (70 eV) m/e 566 (M^+). Anal. Calcd for $C_{32}H_{54}S_2O_4$: C, 67.80%; H, 9.60%; S, 11.31%. Found: C, 67.49%; H, 9.53%; S, 11.40%.

[8] [12]Metacyclophane (80)

To a vigorously stirred mixture of 482.0 mg (1.00 mmol) of bissulfone 72, 8 ml of carbon tetrachloride, 5 ml of cyclohexene, and 10 ml of t-butanol was added 5 g of pulverized potassium hydroxide. Upon further stirring at room-temperature for 12 h, the reaction mixture was poured into 100 ml of water and extracted with petroleum ether (50-75°C). The combined extracts were washed with water, dried over anhydrous magnesium sulfate and evaporated in vacuo to give a yellow oil. The nmr spectrum of this material indicated the presence of both [8][12]metacyclophane-1',11'-diene (76) and, 7,7-dichloro-bicyclo[4.1.0]heptane arising from the absorption of dichlorocarbene by cyclohexene. The bicyclic gem-dichloride was removed by vacuum distillation at 35°C under 0.05 mmHg, leaving relatively pure 76 as indicated by the nmr spectrum of the residue.

The crude diene obtained above was dissolved in 20 ml of ethyl acetate and hydrogenated over 5% palladium on charcoal at room-temperature under 45 psi for 4 h. Removal of catalyst and evaporation of solvent gave a yellow oil

which was taken up in ca 3 ml of petroleum ether (50-75°C) and chromatographed over silica gel (E. Merck 7733). The fraction eluted with petroleum ether (50-75°C) on evaporation gave 178.4 mg (50.4%) of a viscous liquid, which solidified on cooling. Recrystallization of this substance from ethanol gave pure[8][12]metacyclophane (80) as small white prisms: m.p. 55-57°C; nmr (CCl_4) δ ppm 0.52-1.90 (unresolved broad peak, 32H, non-benzylic $-CH_2-$), 2.41-2.80 (overlapped peaks, 8H, benzylic $-CH_2-$), 6.89 (s, 1H, ArH), 7.14 (s, 1H, ArH); Anal. Calcd for $C_{26}H_{42}$: m/e 354.3284. Found: 354.3264.

[12][12]Metacyclophane (81)

To a vigorously stirred mixture of 538.0 mg (1.00 mmol) of bissulfone 73, 8 ml of carbon tetrachloride, 5 ml of cyclohexene, and 10 ml of t-butanol was added 5 g of pulverized potassium hydroxide. Upon further stirring at room-temperature for 12 h, the reaction mixture was poured into 100 ml of water and extracted with petroleum ether (50-75°C). The combined extracts were washed with water, dried over anhydrous magnesium sulfate and evaporated in vacuo to give a yellow oil. The nmr spectrum of this material indicated the presence of both [12][12]metacyclophane-1 ,11 -diene (77) and, 7,7-dichloro-bicyclo[4.1.0]heptane arising from the absorption of dichlorocarbene by cyclohexene. The bicyclic gem-dichloride was removed by vacuum distillation at 35°C under 0.05 mmHg, leaving relatively pure 77 as indicated by the nmr spectrum of

the residue.

The crude diene obtained above was dissolved in 20 ml of ethyl acetate and hydrogenated over 5% palladium on charcoal at room-temperature under 45 psi for 4 h. Removal of catalyst and evaporation of solvent gave a yellow oil which was taken up in ca 3 ml of petroleum ether (50-75°C) and chromatographed over silica gel (E. Merck 7733). The fraction eluted with petroleum ether (50-75°C) on evaporation gave 224.3 mg (54.7%) of a viscous liquid, which solidified on cooling. Recrystallization of this substance from ethanol gave pure [12][12]metacyclophane (81) as white prisms: m.p. 160-162°C; nmr (CCl_4) δ ppm 0.80-1.78 (unresolved broad peak, 40H, non-benzylic $-CH_2-$), 2.35-2.70 (t, J=6Hz, 8H, benzylic $-CH_2-$), 6.75 (s, 2H, ArH). ms (70 eV) m/e 410 (M^+).
Anal. Calcd for $C_{30}H_{50}$: C, 87.73%; H, 12.27%. Found: C, 87.76%; H, 11.88%.

[12][12]Paracyclophane (82)

To a vigorously stirred mixture of 538.0 mg (1.00 mmol) of bissulfone 74, 8 ml of carbon tetrachloride, 5 ml of cyclohexene, and 10 ml of t-butanol was added 5 g of pulverized potassium hydroxide. Upon further stirring at room-temperature for 12 h, the reaction mixture was poured into 100 ml of water and extracted with petroleum ether (50-75°C). The combined extracts were washed with water, dried over anhydrous magnesium sulfate and evaporated in vacuo to give a yellow oil. The nmr spectrum of this material indicated the presence of both [12][12]paracyclophane-1,11-diene (78) and, 7,7-dichlorobicyclo[4.1.0]heptane arising from the absorption of

dichlorocarbene by cyclohexene. The bicyclic gem-dichloride was removed by vacuum distillation at 35°C under 0.05 mmHg, leaving relatively pure 78 as indicated by the nmr spectrum of the residue.

The crude diene obtained above was dissolved in 20 ml of ethyl acetate and hydrogenated over 5% palladium on charcoal at room-temperature under 45 psi for 4 h. Removal of the catalyst and evaporation of solvent gave a yellow oil which was taken up in ca 3 ml of petroleum ether (50-75°C) and chromatographed over silica gel (E. Merck 7733). The fraction eluted with petroleum ether (50-75°C) on evaporation gave 125.5 mg (30.6%) of a viscous liquid, which solidified on cooling. Recrystallization of this substance from ethanol gave pure [12] [12]paracyclophane (82) as small needles: m.p. 92-94°C; nmr (CCl_4) δ ppm 0.50-1.32 (unresolved broad peak, 40H, non-benzylic $-CH_2-$), 2.10-3.19 (m, 8H, benzylic $-CH_2-$), 6.79 (s, 2H, ArH).

Anal. Calcd for $C_{30}H_{50}$: C, 87.73%; H, 12.27%. Found: C, 88.05%; H, 11.99%. Calcd m/e : 410.3913. Found: 410.3906.

[12] [14]Paracyclophane (83)

To a vigorously stirred mixture of 566.0 mg (1.00 mmol) of bissulfone 75, 8 ml of carbon tetrachloride, 5 ml of cyclohexene, and 10 ml of t-butanol was added 5 g of pulverized potassium hydroxide. Upon further stirring at room-temperature

for 12 h, the reaction mixture was poured into 100 ml of water and extracted with petroleum ether (50-75°C). The combined extracts were washed with water, dried over anhydrous magnesium sulfate and evaporated *in vacuo* to give a yellow oil. The nmr spectrum of this material indicated the presence of both [12][14]paracyclophane-1,11-diene (79) and, 7,7-dichlorobicyclo[4.1.0]heptane arising from the absorption of dichlorocarbene by cyclohexene. The bicyclic *gem*-dichloride was removed by vacuum distillation at 35°C under 0.05 mmHg, leaving relatively pure 79 as indicated by the nmr spectrum of the residue.

The crude diene obtained above was dissolved in 20 ml of ethyl acetate and hydrogenated over 5% palladium on charcoal at room-temperature under 45 psi for 4 h. Removal of the catalyst and evaporation of solvent gave a yellow oil which was taken up in *ca* 3 ml of petroleum ether (50-75°C) and chromatographed over silica gel (E. Merck 7733). The fraction eluted with petroleum ether (50-75°C) on evaporation gave 130.5 mg (29.8%) of a viscous liquid, which solidified on cooling. Recrystallization of this substance from ethanol gave pure [12][14]paracyclophane (83) as small prisms: m.p. 69-71°C; nmr (CCl_4) δ ppm 0.52-1.35 (unresolved broad peak, 44H, non-benzylic $-CH_2-$), 2.10-3.20 (m, 8H, benzylic $-CH_2-$), 6.85 (s, 2H, ArH).

Anal. Calcd for $C_{32}H_{54}$: C, 87.60%; H, 12.40%. Found: C, 87.53%; H, 12.47%. Calcd m/e : 438.4225. Found: 438.4219.

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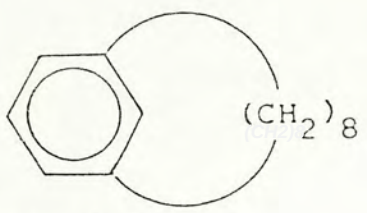
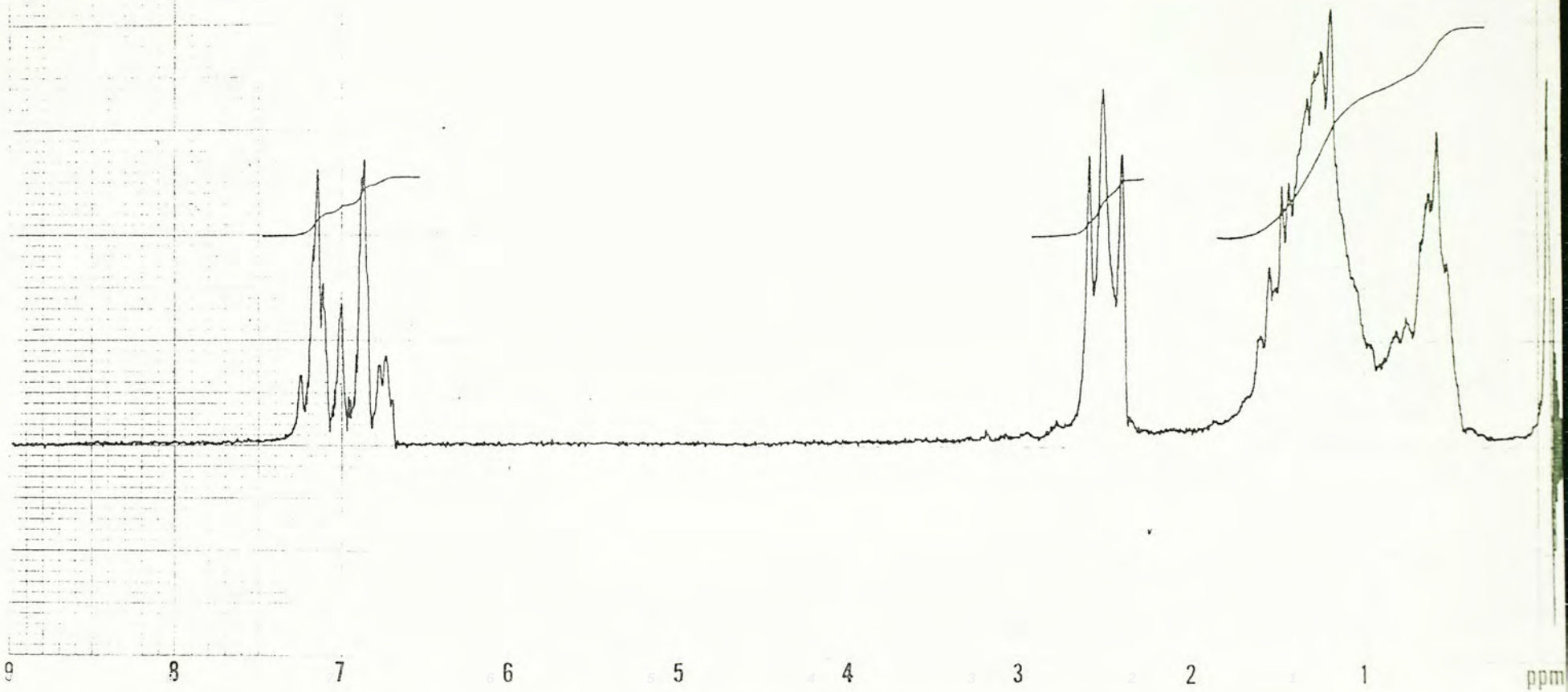
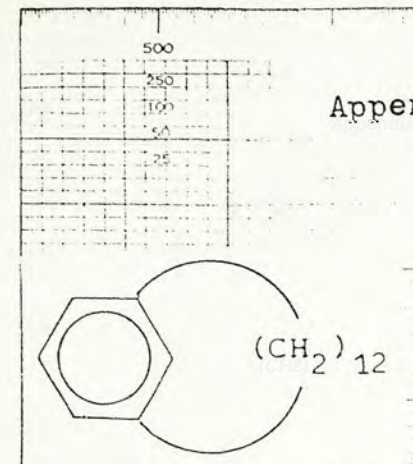
APPENDIX

Appendix 1. Nmr (CCl_4) Spectrum of [8]Metacyclophane (42)

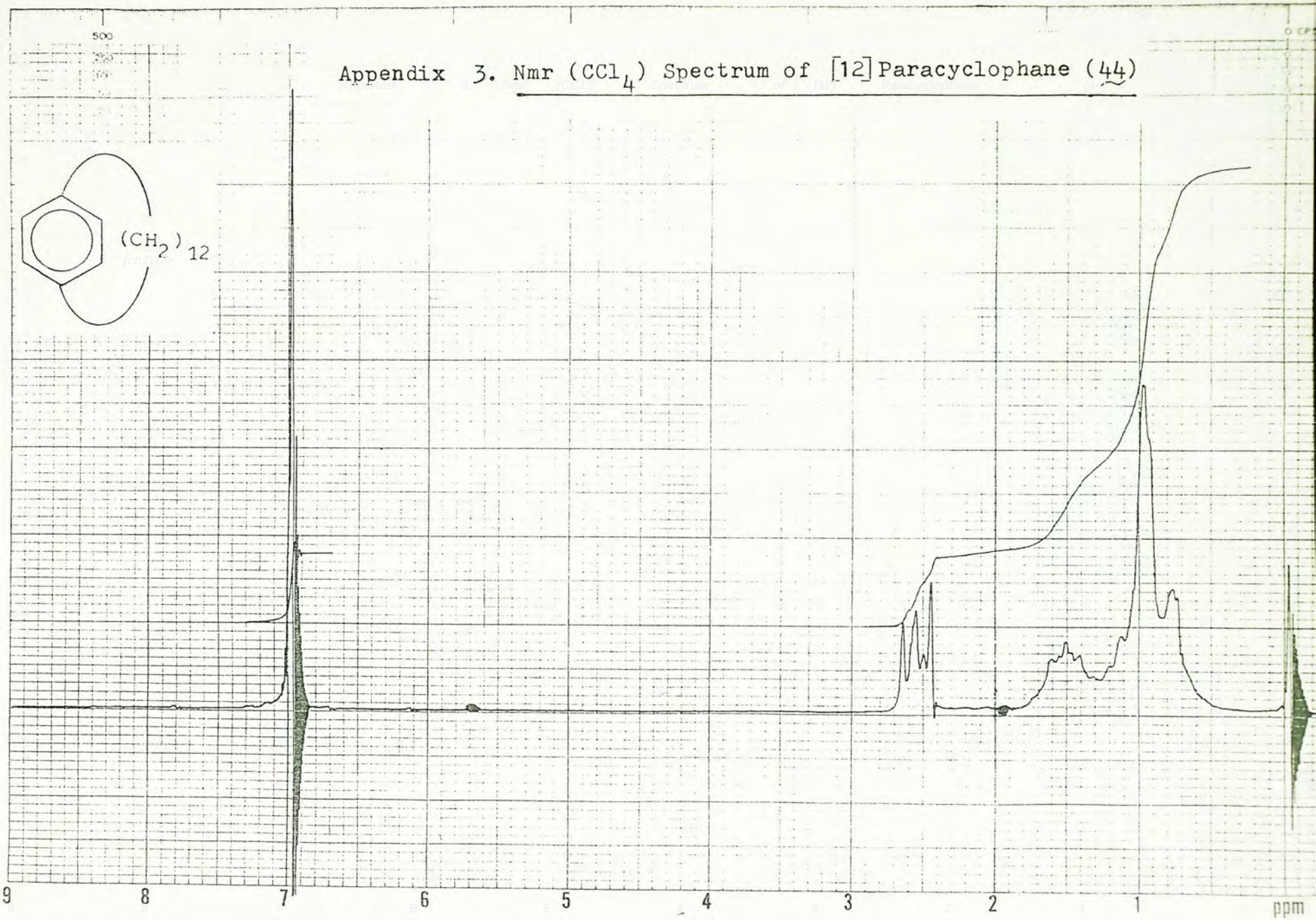




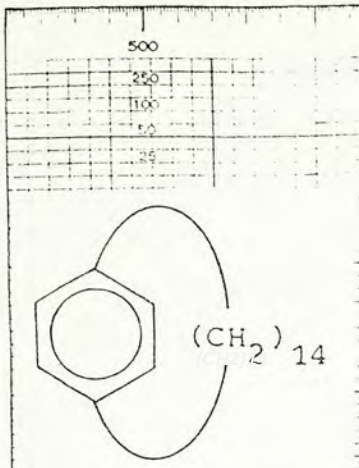
Appendix 2. Nmr (CCl_4) Spectrum of [12]Metacyclophane (43)



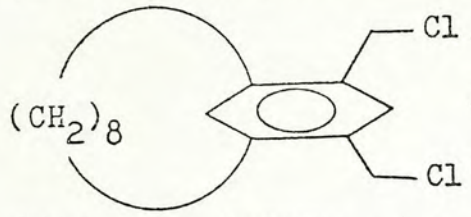
Appendix 3. Nmr (CCl_4) Spectrum of [12]Paracyclophane (44)



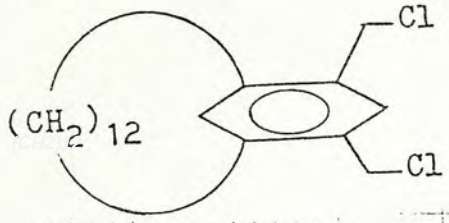
Appendix 4. Nmr (CCl_4) Spectrum of [14]Paracyclophane (45)



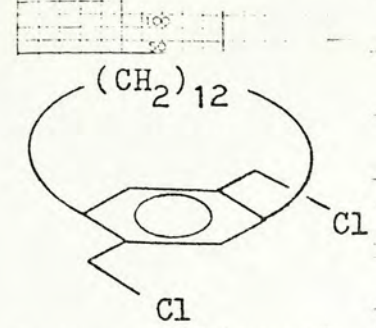
Appendix 5. Nmr (CCl_4) Spectrum of 10,12-Bis(chloromethyl)[8]metacyclophane (46)



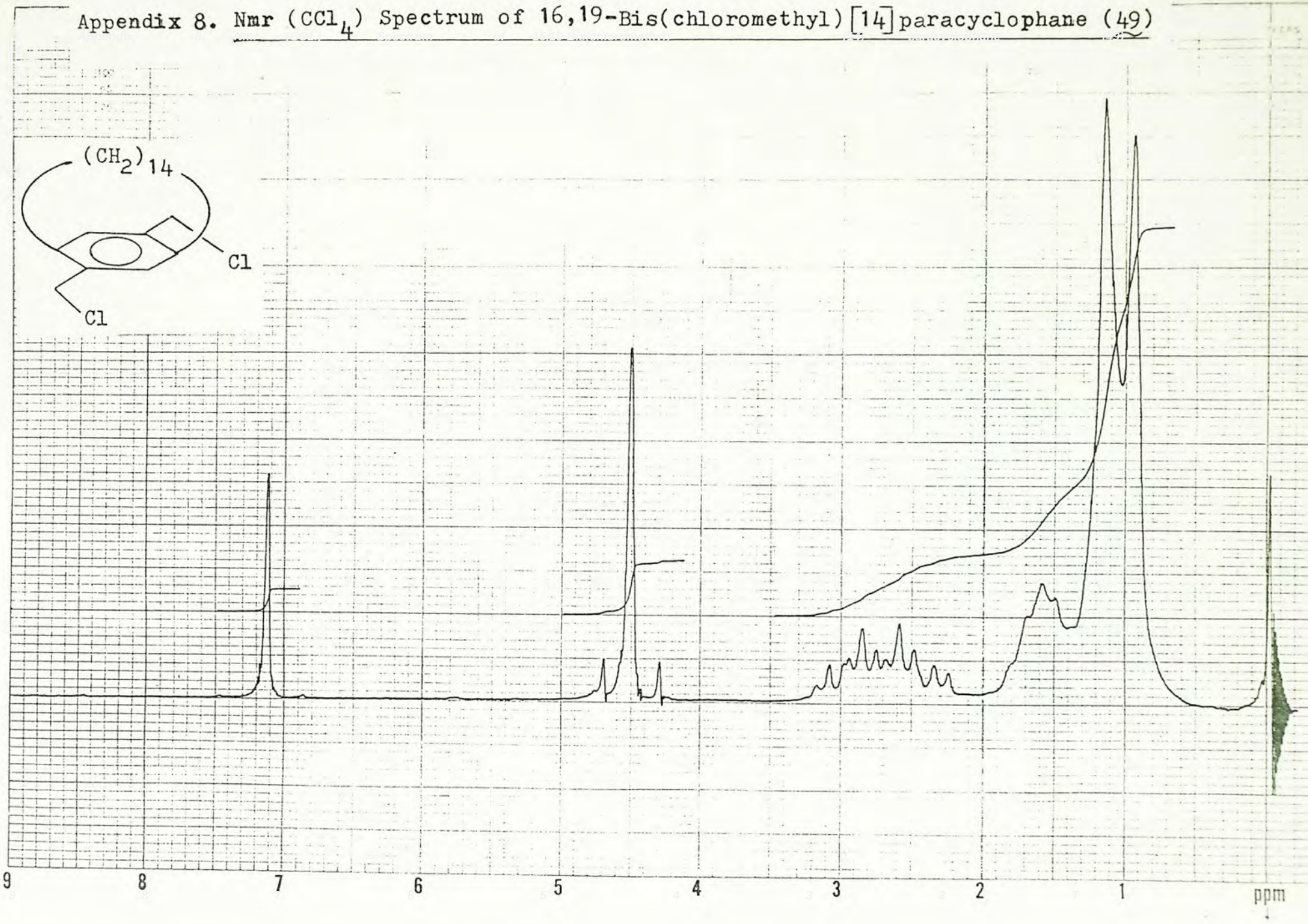
Appendix 6. Nmr (CCl_4) Spectrum of 14,16-Bis(chloromethyl)[12]metacyclophane (47)



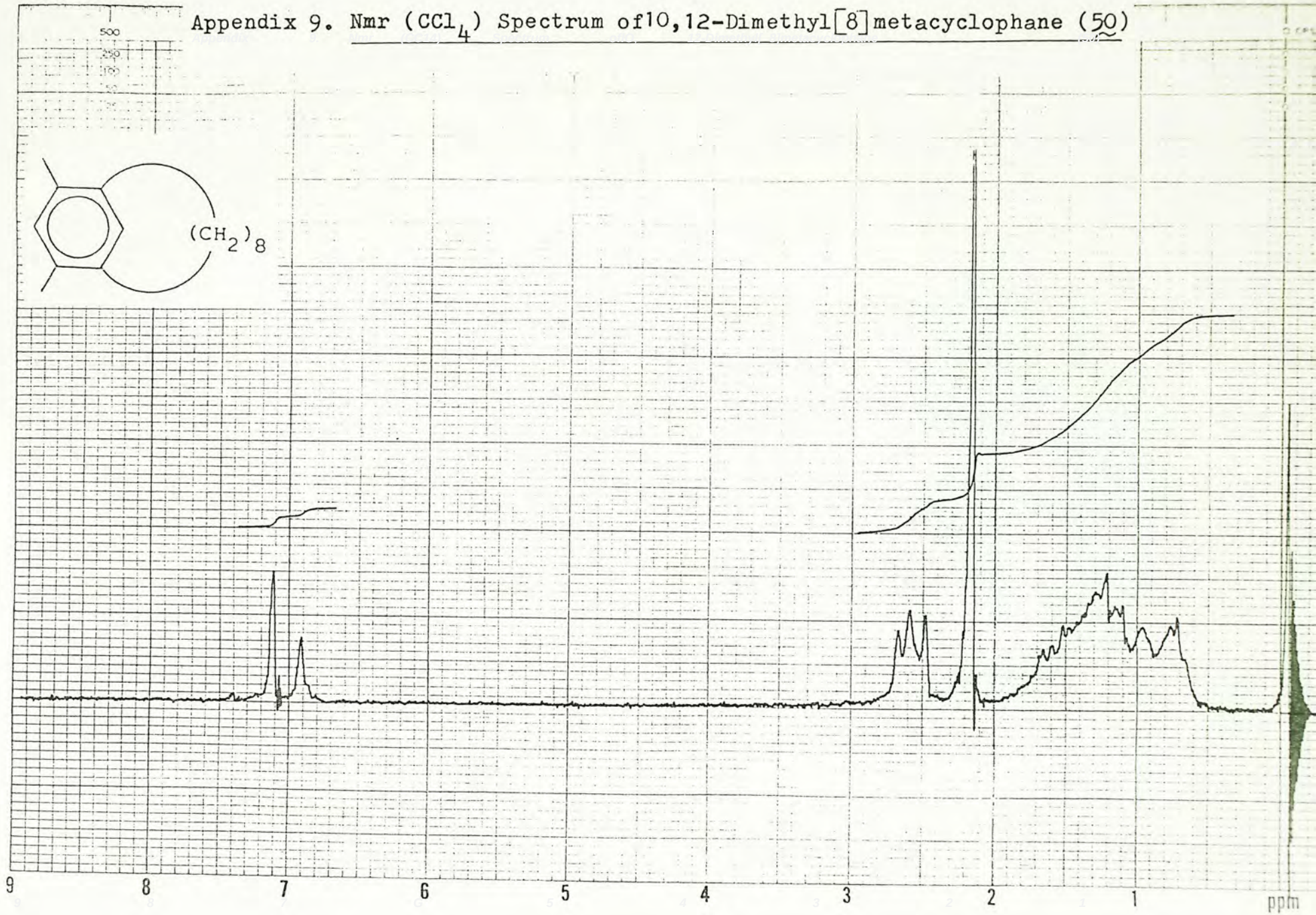
Appendix 7. Nmr (CCl_4) Spectrum of 14,17-Bis(chloromethyl)[12]paracyclophane (48)



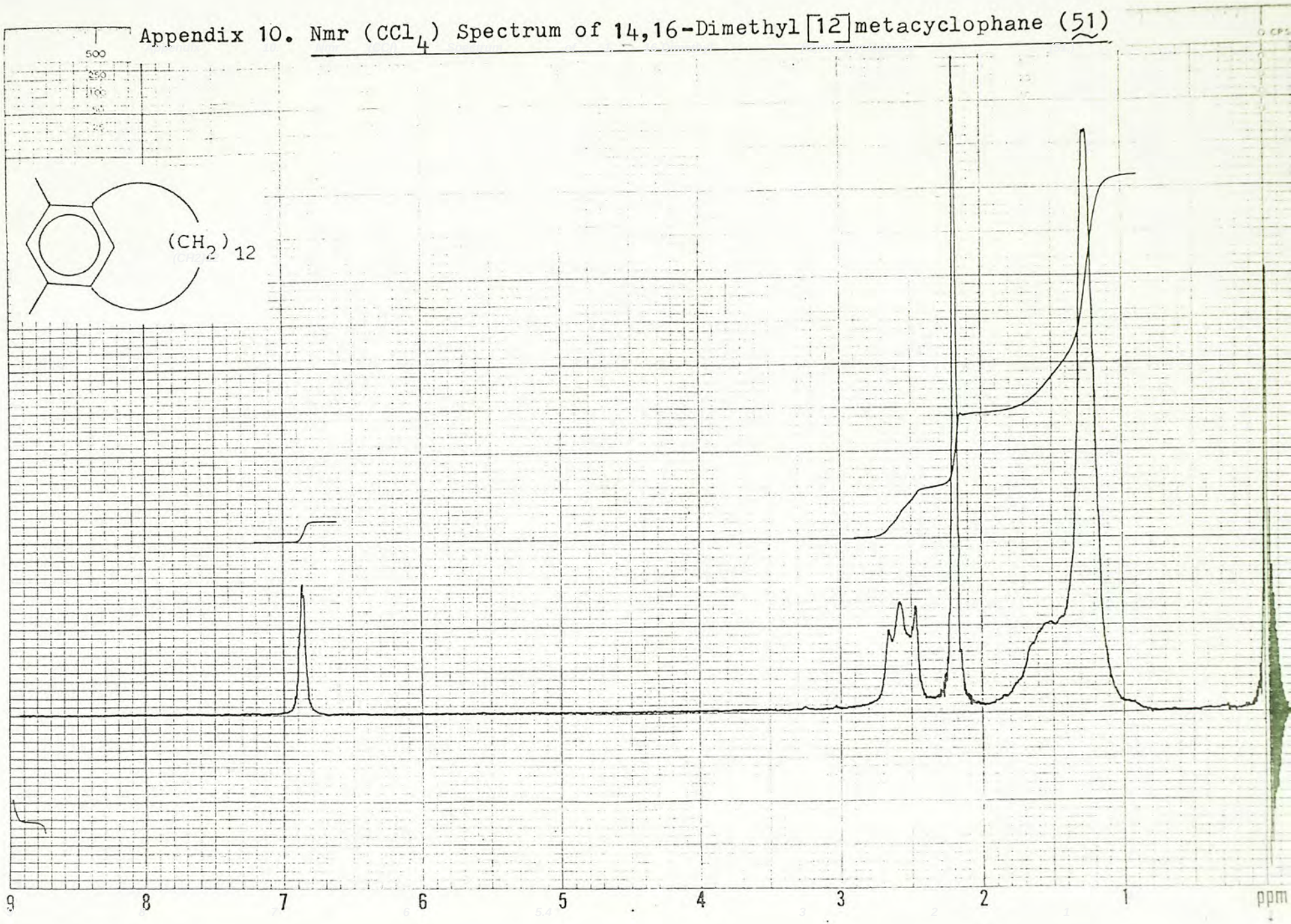
Appendix 8. Nmr (CCl_4) Spectrum of 16,19-Bis(chloromethyl)[14]paracyclophane (49)



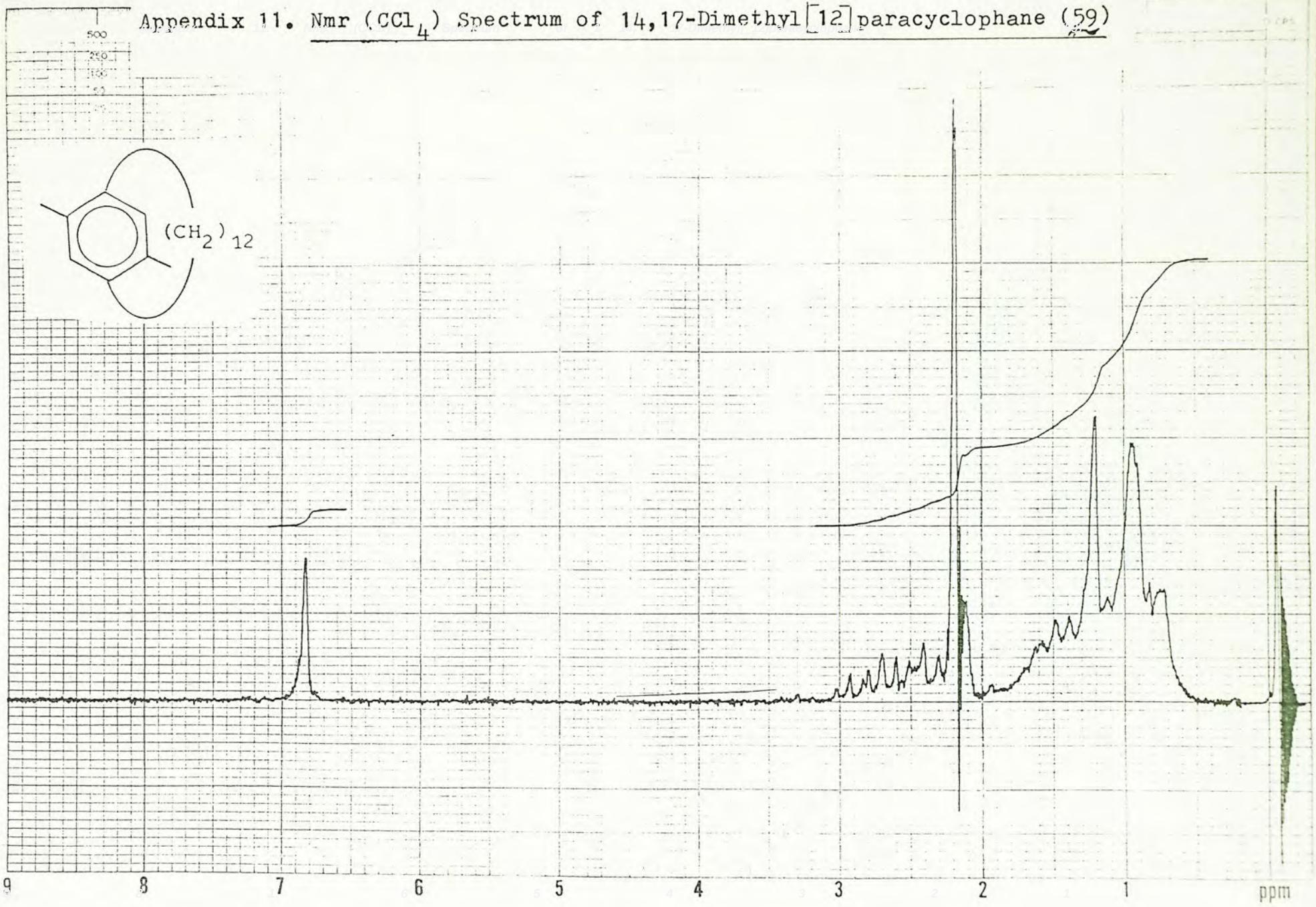
Appendix 9. Nmr (CCl_4) Spectrum of 10,12-Dimethyl[8]metacyclophane (50)



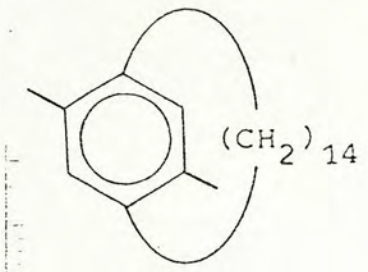
Appendix 10. Nmr (CCl_4) Spectrum of 14,16-Dimethyl [12] metacyclophane (51)

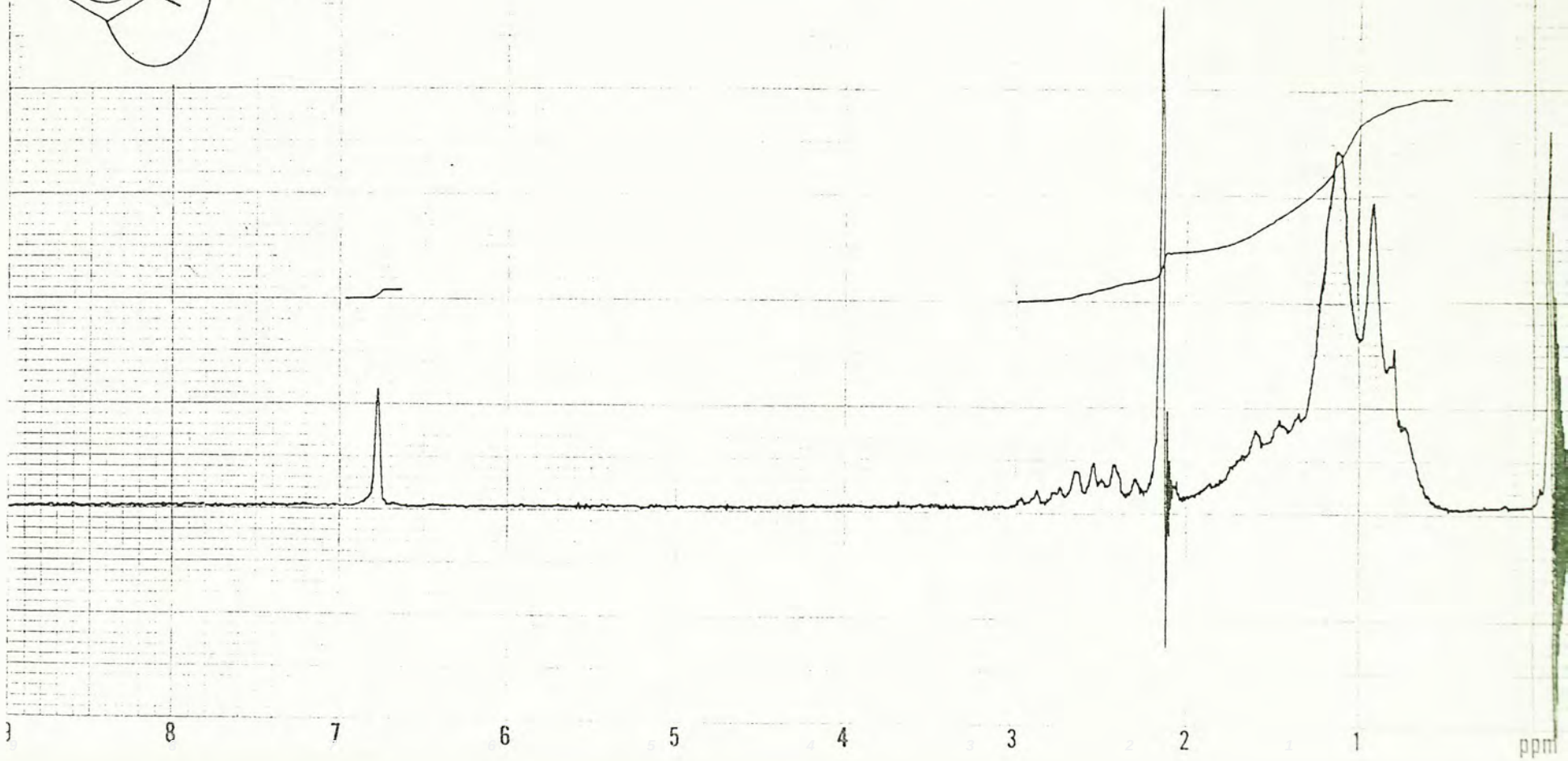


Appendix 11. Nmr (CCl_4) Spectrum of 14,17-Dimethyl[12]paracyclophane (59)

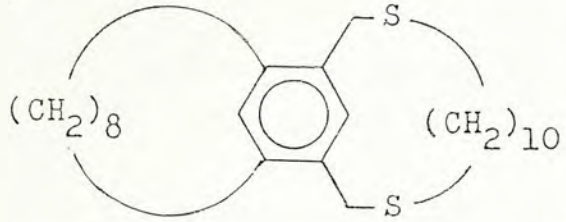


Appendix 12. Nmr (CCl_4) Spectrum of 16,19-Dimethyl [14] paracyclophane (60)

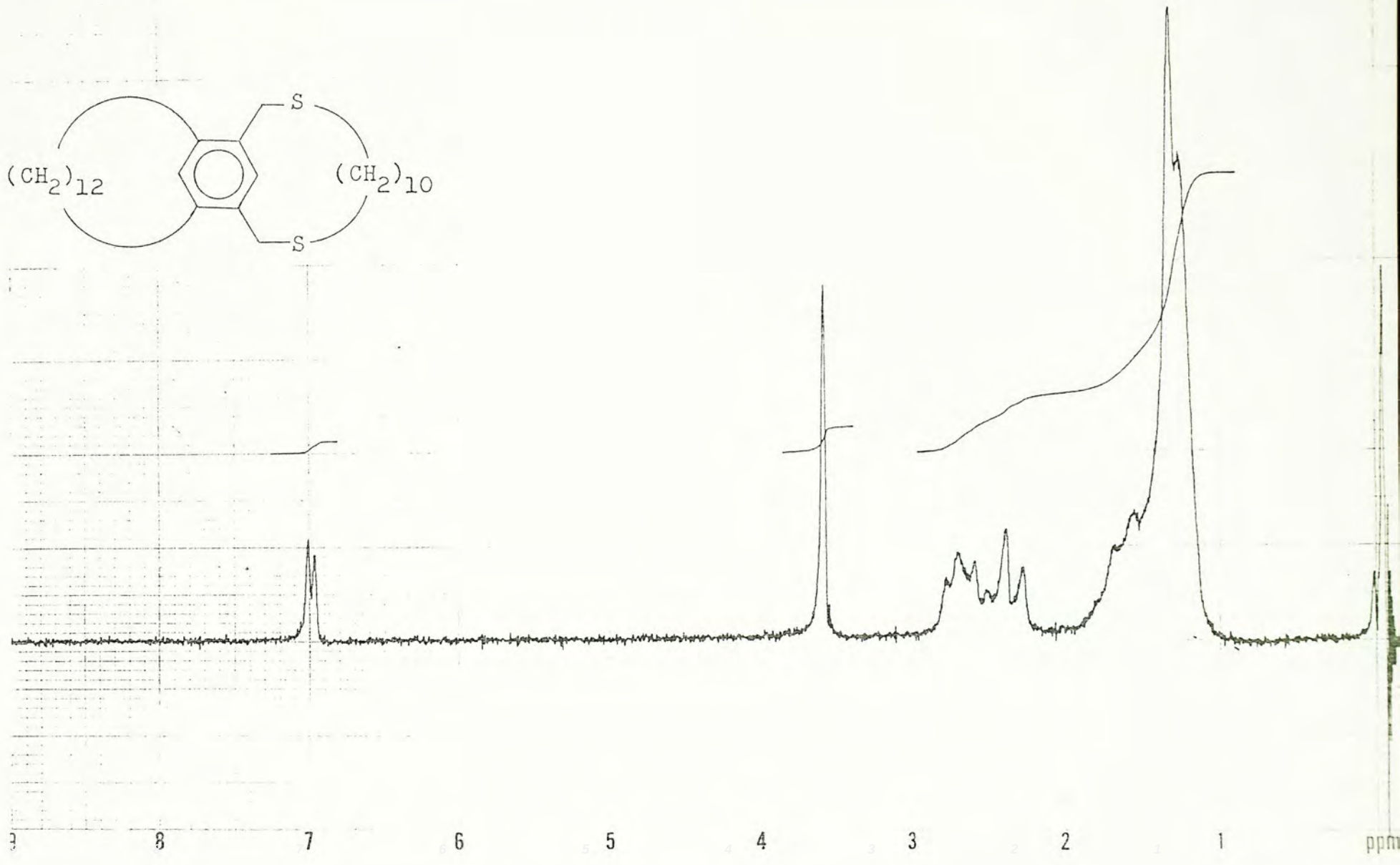




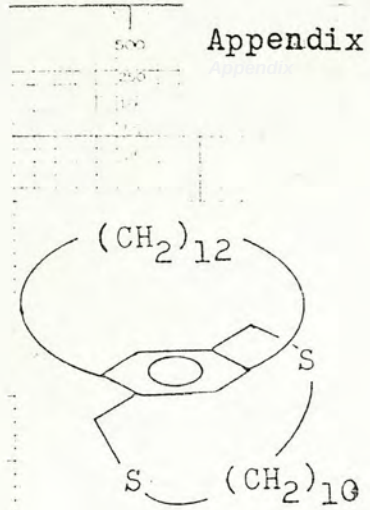
Appendix 13. Nmr (CCl_4) Spectrum of 2',13'-Dithia[8][14]metacyclophane (68)



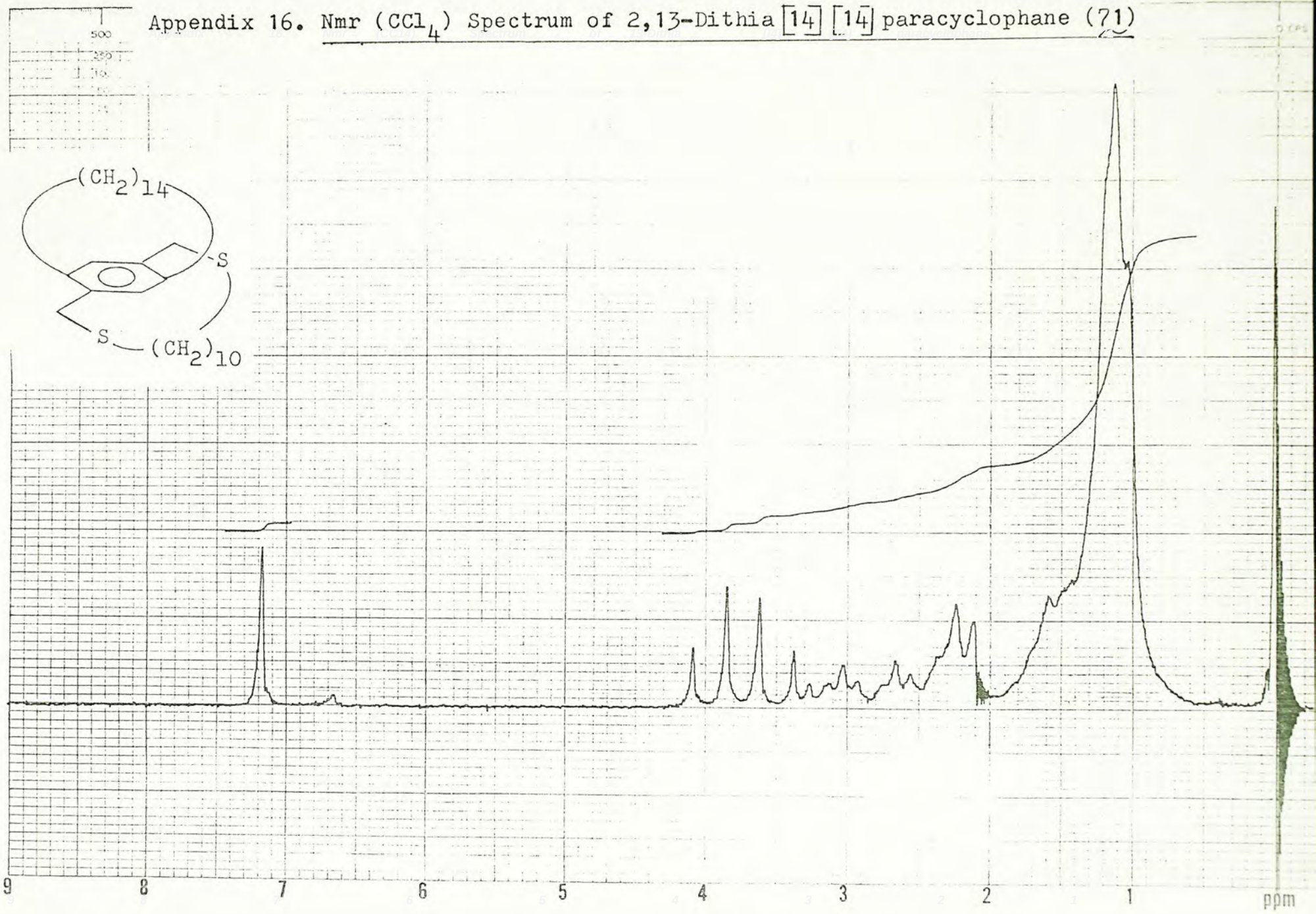
Appendix 14. Nmr (CCl_4) Spectrum of 2',13'-Dithia [12] [14] metacyclophane (69)



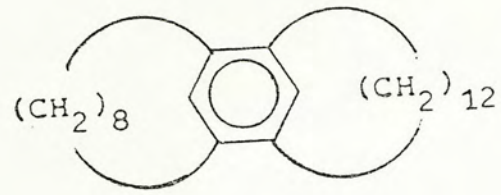
Appendix 15. Nmr (CCl_4) Spectrum of 2',13'-Dithia [12] [14] paracyclophane (70)



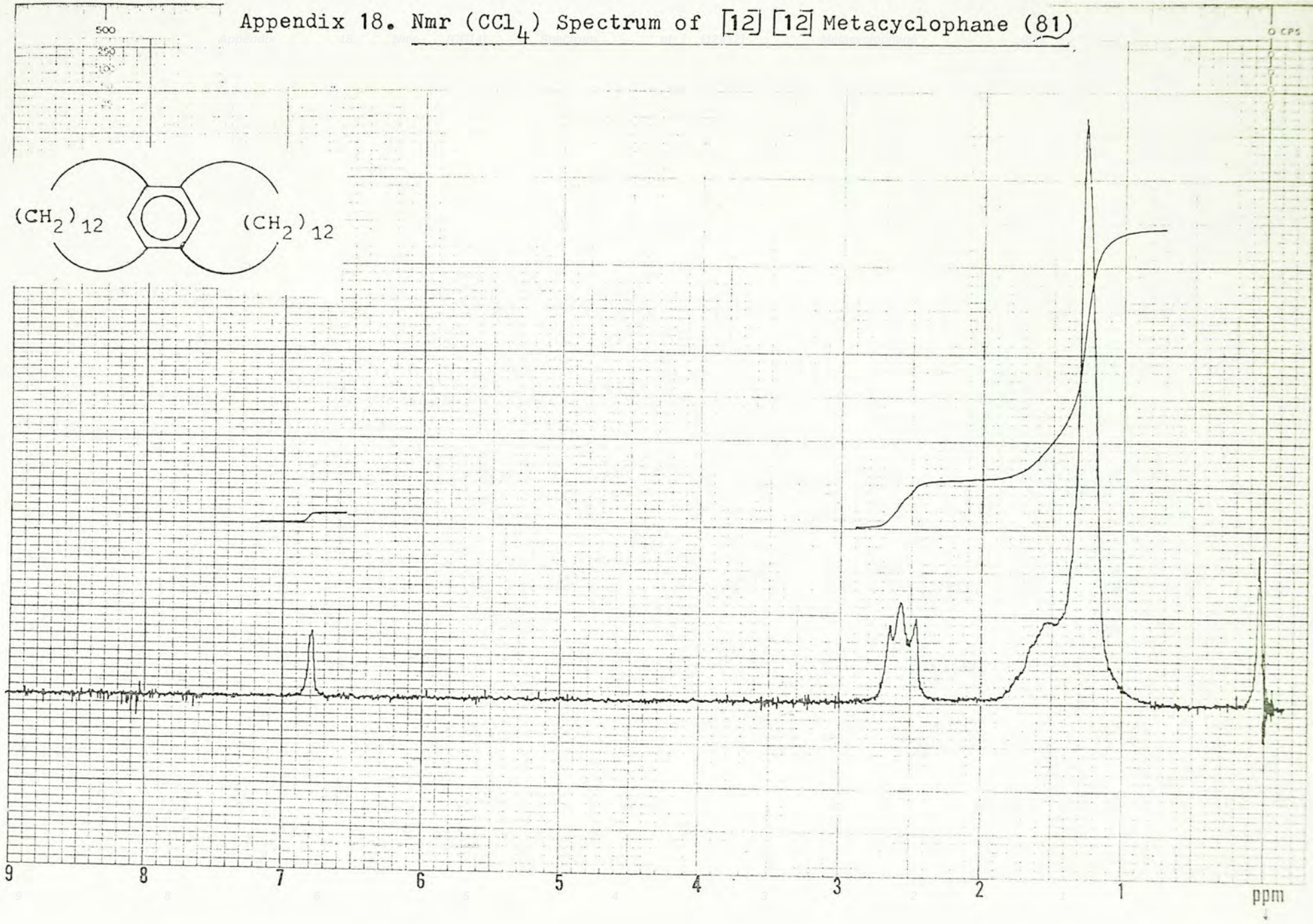
Appendix 16. Nmr (CCl_4) Spectrum of 2,13-Dithia [14] [14] paracyclophane (71)



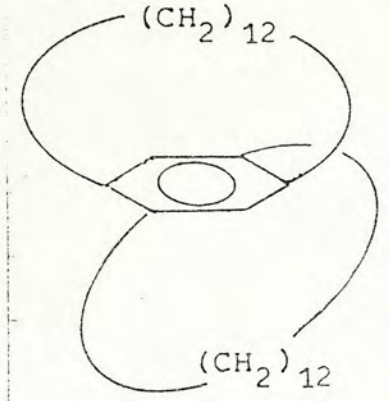
Appendix 17. Nmr (CCl_4) Spectrum of [8][12]Metacyclophane (80)



Appendix 18. Nmr (CCl_4) Spectrum of [12] [12] Metacyclophane (81)



Appendix 19. Nmr (CCl_4) Spectrum of [12] [12] Paracyclophane (82)



Appendix 20. Nmr (CCl_4) Spectrum of [12][14]Paracyclophane (83)